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ARPV SYSTEM/DESIGN TRADE STUDY. VOLUME IV. LAUNCH AND RECOVERY.(U)

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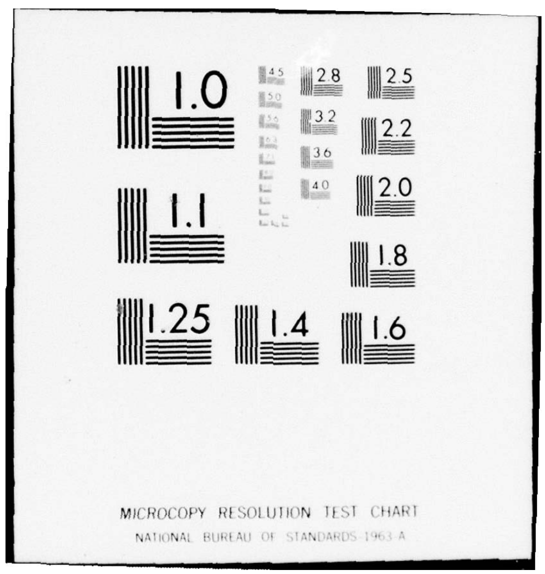
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6 ARPV SYSTEM/DESIGN TRADE STUDY.
VOLUME IV. LAUNCH AND RECOVERY. (U)

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MISSILE SYSTEMS DIVISION

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LAUNCH AND RECOVERY SEGMENT OF ARPV STUDY

TRADE STUDY REPORT

1.0 INTRODUCTION

The statement of work for Advanced RPV System Study directs that the scope of the study program be "extremely broad initially" so that all feasible system technical alternatives are described and analysed leading to a definition of preferred configuration and technical approaches.

In the Launch and Recovery (L&R) segment of the study, the initial set of potential candidate systems is indeed vast, particularly if the morphological approach is considered. This calls for some methodology of reducing this field to a workable level.

The methodology adopted, however, in order to be acceptable had to be free of bias, be technically sound,and in its output selective enough to achieve a valid comparison of the relative applicability and measures of merit between the candidate systems in the L&R field.

A process of selection, elimination and matching of the candidate system elements and the complete systems has been developed on the above guidelines. It is a simplification of the P.O.E.D. (Performance Organization for Evaluation and Decision)* method. It converts a predominatly qualitative evaluation into quantitative terms.

The POED method is a trade study which in the case of L&R segment deals with the cost, design, mission support and operational considerations. It assigns a scale of acceptance and weighting factors to each of the representative descriptor/evaluator criterias and converts them into a Figure of Merit (FOM). Its adoption made possible an early definition of relative merit (including the level of significance) between the systems and their elements.

*POED (Performance Organization for Evaluation and Decision, White, D. R. I; Scott, D. L., and Shultz, R. N., A Method for Evaluating System Performance I.E.E.E. Transactions on Engineering Management, Dec. 1963, pp 177-182

After several iterations, the method produced 16 finalist systems. These in turn were subjected to a life cycle cost study followed by the final cost/benefits/risk POED evaluation.

Several experienced system engineers, some with an extensive operational background, participated in the POED trade studies. The numerical ratings presented in the assessment sheets represent the average of the aggregate ratings assigned to each of the descriptors.

2.0 SELECTION PROCESS

2.1 MORPHOLOGICAL MATRICES OF SYSTEM ELEMENTS

The elements of Launch and Recovery can be considered interacting with a "freebody RPV" through numerous functional and physical interfaces. They can be either specific or common to both the launch and recovery domain. They can be either integral with the vehicle structure or external to it. In turn they connect with the principal force generating system to complete the L&R chain.

The diagram in Figure 2.1-1 shows this generalized arrangement for most of the existing and conceptual elements and their interfaces. This diagram was a basis of a morphological design which resulted in classification of all launch and recovery systems into five generic groups as shown below.

LAUNCH GROUP	RECOVERY GROUP
1. UNASSISTED LAUNCH - CONVENTIONAL TAKE-OFF (Includes STO & VTO) 2. ASSISTED LAUNCH	1. CONVENTIONAL LANDING (Includes S.L.) 2. INTEGRAL VERTICAL (OR NEAR VERTICAL) RECOVERY (INCLUDES V.L.) 3. EXTERNAL RECOVERY

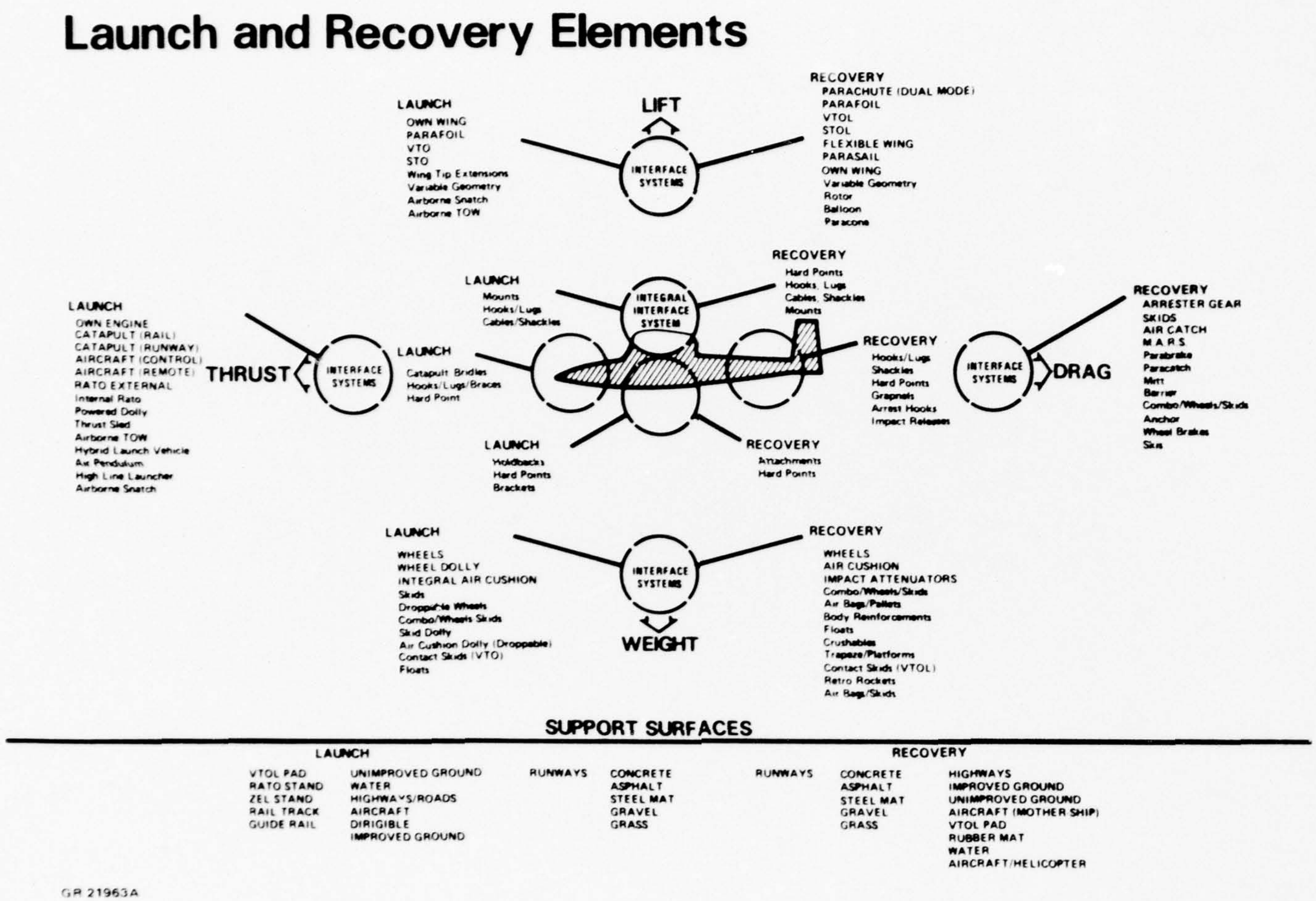


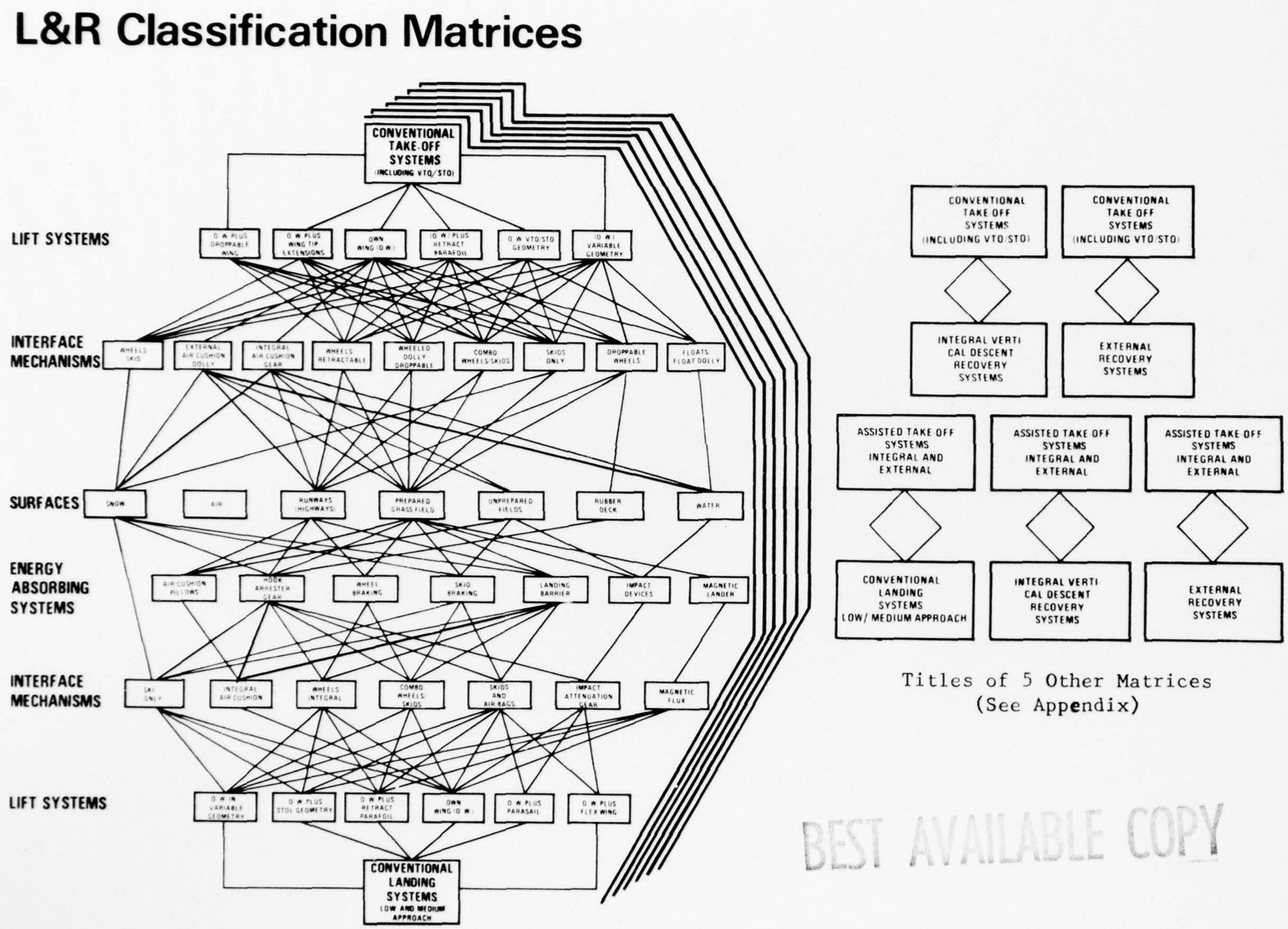
Figure 2.1-1. Launch and Recovery Elements

In turn each group is subdivided into functional or physical interface as follows:

UNASSISTED LAUNCH - CONVENTIONAL TAKE-OFF	(a)	Lift systems with vehicle interfaces
	(b)	Surface/vehicle interface mechanisms
	(c)	Operating surfaces (including air)
ASSISTED LAUNCH	(a)	Lift systems with vehicle interfaces
	(b)	Propulsive assist systems with vehicle interfaces
	(c)	Operating surfaces (including air)
CONVENTIONAL LANDING	(a)	Lift systems including vehicle interfaces
	(b)	Surface/vehicle interface mechanisms
	(c)	Energy absorbing systems
	(d)	Operating surfaces (including air)
INTEGRAL VERTICAL RECOVERY	(a)	Energy absorbing systems
	(b)	Surface/vehicle interface mechanisms
	(c)	Operating surfaces (including air)
EXTERNAL RECOVERY	(a)	Energy absorbing systems
	(b)	Vehicle capture mechanisms
	(c)	Surface/vehicle interface mechanism
	(d)	Operating surfaces (including air)

These five generic groups were paired to produce six morphological matrices each containing the appropriate system elements. A typical resulting matrix is shown in Figure 2.1-2.The entire complement of six - morphological matrices is contained in the Appendix to this report. (Pages A-4 to A-9 .)

The elements are interconnected into feasible system combinations, so that each continuous line from the top to the bottom represents a separate, viable launch and recovery candidate that needs to be considered in the analysis.



Titles of 5 Other Matrices
(See Appendix)

Figure 2.1-2. Conventional (Unassisted) Take-Off and Conventional Landing RPV System Matrix

In all, there could be thousands of potential systems, presenting an impossible task if each was to be treated individually in the analysis. The approach adopted, therefore, was to assess within each generic group, laterally, pertinent launch and recovery elements within a hypotethical airframe to select the most promising and practical and to eliminate those which the analysis showed to be less practical. The remaining "grey area" subsystems were then traded off individually for either retention or elimination.

This process of elimination gradually reduced the number of elements in the matrix. Care had to be taken in not eliminating an element which when standing alone appeared impractical, but could work successfully in combination with others as a part of a viable system.

2.2 SIMPLIFIED P.O.E.D. METHOD

The selective process of potential candidate systems, many of which were just paper concepts necessarily dealt with predictions which could be only based on judgments which, in turn, stemmed from experience and cumulative group knowledge of multitude of operational systems, their method of operation and their associated interfaces. A block diagram typical of this "judgmental" process is shown in Figure 2.2-1. In the example, there are four systems to be assessed and ranked. The assessing engineering group considers the candidate systems in terms of the data bank available which comprises: a) past history of similar systems configuration and performance, b) group's individual engineering background and operational experience, and c) the operational and functional requirements input from the user. A set of descriptor/evaluator criteria is then developed together with the rating scales and corresponding weighting factors. The assignment of rating factors is made on the principle of probability of "acceptance". The highest rating in the

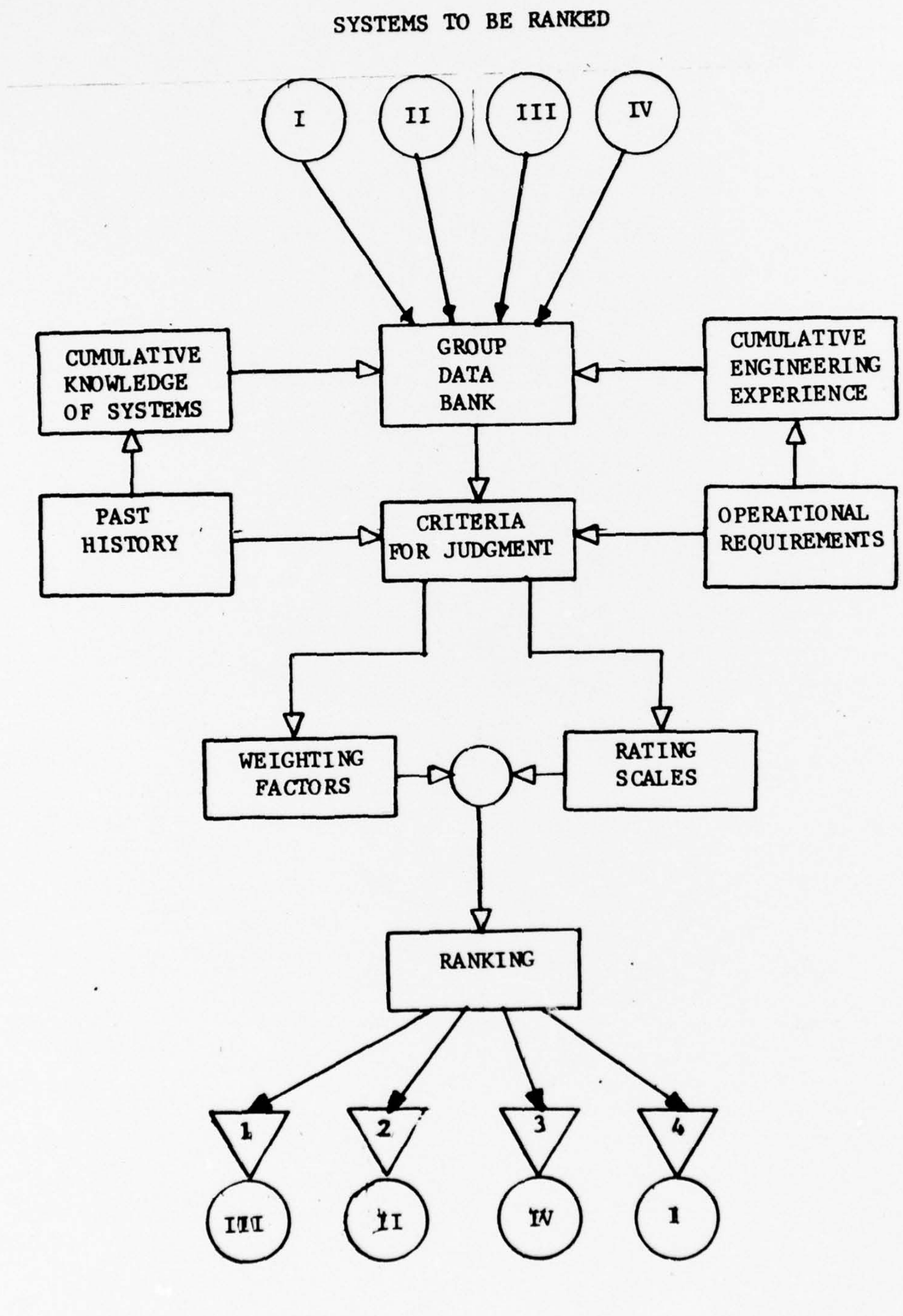


Figure 2.2-1. The Judgmental Ranking Process

scale is seven (7) rated "excellent" and it gives highest probability of acceptance. The scale steps down in increments of unity (fractional values are permitted) to zero (0) which is an unacceptable rating and invalidates the concept under consideration.

The ranking process give the normalized figure of merit (F.O.M.)

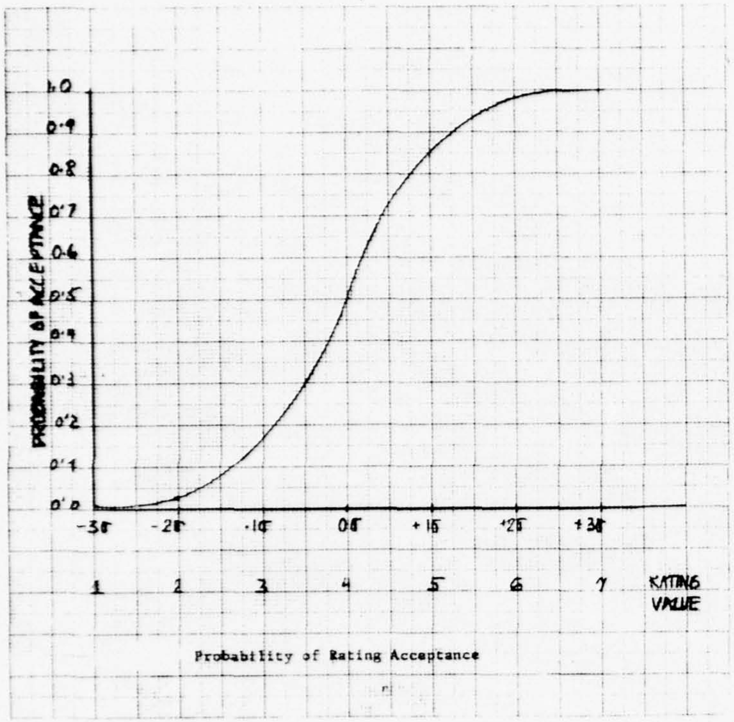
$$F.O.M._j = \frac{\sum_{n=1}^{n} W_i \cdot A_j}{\sum_{n=1}^{n} W_i}$$

Where: W_i = the numerical value of operational weighting factor

A_j = the numerical value of scale of acceptance

The rating scale values for the ARPV launch and recovery concepts together with their probabilistic counterparts are shown in Figure 2.2-2. It should be noted that the rating number of three "3" represents less than average rating and is equivalent to the present system status. This rating allocation was based on the analysis and the evaluation of the existing system (BGM-34C) within the terms of the descriptor criteria for the ARPV trade study using the same weighting factors and the original rating scale with the median at 4.0. In other words, the system to be rated "average" in this trade study must demonstrate or at least promise a better performance than the present operational system.

Figure 2.2-3, the assessment sheet, gives an example of a typical working sheet of the rating process pertaining, in this case, to conventional (unassisted) take-off methods employing seven different types of RPV lift systems. There are 14 descriptor-criteria and their weighting factors, once chosen, remain unaltered during the comparative inter and intra system assessments.



Qualitative Description of Ratings and Probability of Acceptance		
QUALITATIVE DESCRIPTION (Descriptor-Criterion Expected to be:)	RATING NO.	PROBABILITY OF ACCEPTANCE
Order of Magnitude Better than Present System	7	Excellent
Considerably Better than Present	6	Very Good
Much Better than Present	5	Good
Better than Present	4	Average
About the Same as Present	3	Less than Average
Worse than Present	2	Poor
Considerabl Worse than Present	1	Very Poor
Order of Magnitude Worse than Present	0	Unacceptable (Invalidates Concept)

Figure 2.2-2. System Rating Scale and Probability of Acceptance

A_j

SCALE OF ACCEPTANCE

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

L&R SYSTEM EVALUATION
CONVENTIONAL TAKE OFF SYSTEMS

$$FOM_j = \frac{\sum_{i=1}^{14} W_i \; A_j}{\sum_{i=1}^{14} W_i}$$

W_i

OPERATIONAL WEIGHTING FACTORS

10.0	EXTREMELY IMPORTANT
7.0	IMPORTANT
5.0	AVERAGE EFFECT
3.0	LESS THAN AVERAGE EFFECT

W_i WEIGHT FACTOR	CRITERIA	O.W. PLUS DROPABLE WING	O.W. PLUS WING TIP EXTENSIONS	OWN WING (O.W.)	O.W. PLUS RETRACT-PARAFOIL	O.W. STOL GEOMETRY	O.W. VARIABLE GEOMETRY	V.T.O.L.
10.0	COST	2/20	4/40	6/60	3/30	3/30	2/20	1/10
10.0	COMPLEXITY	3/30	4/40	6/60	3/30	3/30	2/20	2/20
10.0	SURVIVABIL.	5/50	5/50	3/30	6/60	6/60	6/60	2/20
5.0	TECHNICAL RISK	3/15	4/20	7/35	3/15	4/20	3/15	2/10
7.0	FLEXIBILITY	3/21	4/28	3/21	5/35	6/42	6/42	7/49
10.0	LAUNCH RATE	2/20	5/50	6/60	4/40	6/60	6/60	6/60
5.0	AVAILABIL.	2/10	4/20	5/25	4/20	4/20	3/15	3/15
7.0	HANDLING	2/14	4/28	6/42	3/21	4/28	4/28	3/21
7.0	VEHICLE COMPATIBIL.	3/21	4/28	6/42	3/21	3/21	3/21	3/21
5.0	SYSTEM COMPATIBIL.	2/10	3/15	6/30	5/25	4/20	4/20	5/25
10.0	LOGISTICS REQMTS.	1/10	2/20	5/50	4/40	4/40	4/40	4/40
7.0	FACILITIES REQMTS.	4/28	6/42	2/14	3/21	5/35	5/35	6/42
7.0	PECULIAR EQUIPMENT	3/21	3/21	6/42	4/28	5/35	5/35	3/21
7.0	VEHICLE WT. CONTRIBUTION	3/21	5/35	4/28	3/21	3/21	3/21	2/14
	TOTAL	38/291	57/437	71/539	53/407	60/462	56/432	49/368
	FIGURE OF MERIT	2.71/2.71	4.07/4.08	5.02/5.03	3.78/3.80	4.28/4.31	4.0/4.03	3.5/3.43
	RANK NUMBER	7	3	1	5	2	4	6

Figure 2.2-3. Assessment Sheet (Example)

The detailed definition of 14 descriptor/evaluator criteria with corresponding weighting factors used in the ARPV Launch & Recovery POED trade study can be found in Table 2.2-1 and 2.2-2. A rationale for the selection of the weighting factor is also included.

A step by step procedure followed during POED assessment was as follows:

1. From systems under consideration select three systems:
   a. Present (or nearest to present), (a) most acceptable, (c) least acceptable system
   b. Assign level of acceptance to present system
   c. Assign levels of acceptance to most acceptable and least acceptable systems.
   d. Interpolate and locate other system rating in terms of the three basic acceptance levels (b) and (c) above.
2. Introduce weighting factor effects for each position in the matrix and place the results on the right of the unweighted rating.
3. Sum up unweighted and weighted ratings into totals
4. Obtain unweighted and weighted Figure of Merit by dividing unweighted total by 14(number of descriptors) and weighted total by the sum of weighting factors (in the example shown - this number is 107).
5. Compare unweighted FOM(FOM_{UNW}) with weighted FOM(FOM_W). A large percentage increase in weighted FOM as compared with unweighted FOM indicates that the system scores heavily in the criteria that are important to the system operation. The opposite is true when the FOM_W is smaller than FOM_{UNW}. This characteristic is helpful during final ranking, should two or more systems be close in FOM ratings.
6. Assign rank to each system.

Note: In this report, for the sake of clarity, only the weighted ratings are presented in the assessment sheets that follow.

Table 2.2-1 Descriptor Criteria Definition
(Includes Weighting Factors)

DESCRIPTOR CRITERIA DEFINITION
(INCLUDES WEIGHTING FACTORS)

DESCRIPTOR	FACTORS INCLUDED IN DESCRIPTOR	WEIGHT FACTOR	DEFINITION OF WEIGHT FACTOR	
1. COST	COST PER LAUNCH	10	RATED HIGH. TOTAL SYSTEM COST IS ONE OF THE PRIMARY FACTORS IN EVALUATION OF SYSTEM APPLICABILITY AND UTILITY IN THE RPV FIELD	ASSES L&R S ARPV.
2. COMPLEXITY	PRODUCIBILITY	10	RATED HIGH BECAUSE IT IS THE PRIMARY DRIVER IN COMPOUNDING MANPOWER, MATERIAL AND FUNCTIONAL REQUIREMENTS IN SYSTEM ACQUISITION AND OPERATION	INCLU 1) N C 2) C I 3) L I
3. SURVIVABILITY	LAUNCH & RECOVERY PERFORMANCE RECOVERY DISPERSION	10	RATED HIGH BECAUSE IN FIELD OPERATION IT IS THE MAIN DRIVER OF TURN AROUND TIME, AND SORTIE RATES. IT EITHER ACTIVATES OR DEACTIVATES THE LOGISTIC CHAIN	PREDO LAUNC SIDER AND D VELOC EASE LAUNC EFFEC
4. TECHNICAL RISK	--	5	RATED LOW TO ALLOW SCOPE FOR SYSTEMS THAT ARE INOVATIVE AND CONCEPTUAL AND HAVE NOT BEEN PROVEN YET EITHER ANALYTICALLY OR IN PRACTICE.	TIME ASSUM TECHN PRACT PROCE OFF-T NEW P BE ME
5. FLEXIBILITY	OPERATIONAL FLEXIBILITY MOBILITY (½)	7	RATED MEDIUM/HIGH - ARPV SYSTEM CONCEPT ASSUMES THREE PERMANENT BASES IN DEPLOYMENT. THESE BASES WILL BE PREPARED TO A DESIRED LEVEL AND SYSTEM FLEXIBILITY CAN BE EXERCISED WITHIN THESE BASES AT LEAST INITIALLY. IN VIEW OF THE C^3 SUPPORT REQUIREMENT FOR ARPV OPERATIONS IT IS NOT VERY LIKELY THAT AN "IMPROMPTU" DEPLOYMENT WILL BE MADE FROM JUST ANYWHERE AT ANY TIME.	ABILI WEATH DAMAG TENAN FIELD SYSTE
6. LAUNCH RATE	TURN AROUND TIME AND ITS IMPACT ON LAUNCH RATE	10	RATED HIGH - THIS BEING THE PREREQUISITE OF ARPV SYSTEM ACCEPTABILITY AS AN OPERATIONAL COMBAT WEAPON SYSTEM FOR EMPLOYMENT IN AN OPERATIONAL THEATER.	NUMBE BASIS
7. AVAILABILITY	RELIABILITY MAINTAINABILITY	5	RATED LOW - ASSUMING A SYSTEM DESIGNED TO A REQUIRED LEVEL OF RELIABILITY AND MAINTAINABILITY - IT IS IN THE FIELD A FUNCTION OF PLANNING, MANAGEMENT AND PROPER EXECUTION OF MAINTENANCE AND LOGISTIC SUPPORT CONCEPTS.	ASSES OPERA ASSES STATU ABOVE OF FI

iptor Criteria Definition
udes Weighting Factors)

2

CRITICAL DEFINITION
WEIGHTING FACTORS)

ITION FACTOR	DEFINITION OF DESCRIPTOR
TAL SYSTEM COST IS ARY FACTORS IN YSTEM APPLICABILITY THE RPV FIELD	ASSESSMENT IS MADE ON THE LIFE CYCLE COST CONTRIBUTION OF THE L&R SYSTEM OR ITS ELEMENT TO THE TOTAL LIFE CYCLE COST OF THE ARPV.
USE IT IS THE IN COMPOUNDING IAL AND IREMENTS IN ION AND OPERATION	INCLUDES THREE KINDS OF COMPLEXITIES: 1) <u>MANUFACTURE & ASSEMBLY</u> - NUMBER OF COMPONENT PARTS, NUMBER OF INTER & INTRA SUBSYSTEM INTERFACES, ABILITY TO MODULARIZE 2) <u>OPERATIONAL</u> - NUMBER OF ASSOCIATED FUNCTIONS & OPERATIONS, NUMBER OF PEOPLE & SKILLS & SUPPORT REQUIRED 3) <u>LOGISTICS</u> - NUMBER OF COMPONENT PARTS, KITS, FUNCTIONS WHILE IN STORAGE, ENVIRONMENTAL REQUIREMENTS
USE IN FIELD THE MAIN DRIVER TIME, AND SORTIE ER ACTIVATES OR LOGISTIC CHAIN	PREDOMINANTLY L&R CONTRIBUTION TO VEHICLE SURVIVABILITY DURING LAUNCH AND RECOVERY OPERATIONS. EFFECTS OF ENEMY FIRE CONSIDERED ONLY IF THIS AFFECTS VEHICLE SURVIVAL PRIOR TO LAUNCH AND DURING RECOVERY THROUGH EASE OR RESISTANCE DAMAGE. IMPACT VELOCITIES AND EFFECTS OF WIND ON VEHICLE DAMAGE. DIFFICULTY OR EASE OF DISPERSION CONTROL AND PREDICTION. CONTROLLABILITY IN LAUNCH & RECOVERY FLIGHT PHASES IN PRESENCE OF ENVIRONMENTAL EFFECTS - WIND.
LOW SCOPE FOR E INOVATIVE AND HAVE NOT BEEN ER ANALYTICALLY	TIME AND ENGINEERING EFFORT NECESSARY TO DEVELOP THE L&R SYSTEM. ASSUMES THAT ALL CONCEPTS ARE CONSIDERED FEASIBLE. IF NEW TECHNOLOGY IS NEEDED - WHAT IS THE LEVEL OF DEPARTURE FROM PRACTICES, MATERIALS, EQUIPMENT, REQUIREMENTS. NEED FOR NEW PROCESSES OR MATERIALS. NEW LEVELS OF ACCURACY IN CONTROL. CAN OFF-THE-SHELF EQUIPMENT BE COMPONENT PARTS OR DOES IT REQUIRE A NEW PIECE OF EQUIPMENT TO OPERATE. CAN THE SCHEDULES PROPOSED BE MET WITH REASONABLE CONFIDENCE?
<u>GH</u> - ARPV SYSTEM THREE PERMANENT MENT. THESE BASES D TO A DESIRED LEVEL IBILITY CAN BE EXER- ESE BASES AT LEAST VIEW OF THE C^3 SUP- T FOR ARPV OPERATIONS LIKELY THAT AN "IM- MENT WILL BE MADE ERE AT ANY TIME.	ABILITY TO OPERATE IN DIVERSE OR CHANGING CONDITIONS OF CLIMATE, WEATHER, TIME OF DAY/NIGHT, TERRAIN MANPOWER, SUPPORT LEVEL, DAMAGE TO SITES BY ENEMY ACTION. THE DEGREE OF CHANGE OR MAINTENANCE OR SUPPORT EFFORT REQUIRED TO MEET THESE CHANGES IN THE FIELD. SYSTEM MOBILITY ON CHANGE OF SITES.
IS BEING THE ARPV SYSTEM S AN OPERATIONAL YSTEM FOR EMPLOY- ATIONAL THEATER.	NUMBER OF LAUNCH AND/OR RECOVERIES CAPABILITY ON A SUSTAINED BASIS - RATHER THAN FIRST WAVE BASIS.
UMING A SYSTEM EQUIRED LEVEL OF MAINTAINABILITY - ELD A FUNCTION OF EMENT AND PROPER INTENANCE AND T CONCEPTS.	ASSESSMENT IS MADE OF THE VALUE OF CLASSICAL QUOTIENT OF OPERATING TIME TO THE SUM OF OPERATING TIME AND DOWN TIME. ASSESS PROBLEMS OR OTHERWISE IN MAINTAINING THE SYSTEM IN USABLE STATUS. PROBABILITY OF DETERIORATION OF THE SYSTEM OVER AND ABOVE PREDICTED RELIABILITY LEVELS. ADVERSE OR OTHERWISE EFFECTS OF FIELD ENVIRONMENT ON SYSTEM SERVICABILITY.

Table 2.2-2 Descriptor Criteria Definition (Cont'd)
(Includes Weighting Factors)

DESCRIPTOR	FACTORS INCLUDED IN DESCRIPTOR	WEIGHT FACTOR	DEFINITION OF WEIGHT FACTOR	
8. HANDLING	SAFETY MOBILITY (½)	7	RATED MEDIUM/HIGH. AN IMPORTANT OPERATIONAL FACTOR WITH POWERFUL EFFECT ON TURN-AROUND TIME.	ASSESSMEN TRANSPORT AND SERVI SKILL LEV PORTABILI UNDER OWN ARMAMENT
9. VEHICLE COMPATIBILITY	--	7	RATED MEDIUM/HIGH. AN IMPORTANT FACTOR AFFECTING VEHICLE DESIGN. DETERMINES WHETHER THE L&R SYSTEM IS LIKELY OR OTHERWISE TO AFFECT THE ACCEPTED AERODYNAMIC CONFIGURATION CONCEPTS OF SHAPE, SIZE AND POWER REQUIREMENTS	THIS DESC POTENTIAL BODY WITH ARPV MISS THESE POS DRAG, LOW ABILITY T ABILITY T OR EXTERN
10. SYSTEM COMPATIBILITY	CDRS COMPATIBILITY	5	RATED LOW. MOST OF THE L&R SYSTEMS HAVE ONLY AN AVERAGE IMPACT ON TOTAL ARPV SYSTEM AS IT IS UNDERSTOOD TODAY AS THEY ARE ALL ASSUMED COMPATIBLE BEFORE INCLUSION IN THE STUDY. AS THE ARPV SYSTEM CAN ACCEPT A GREAT VARIETY OF L&R SYSTEMS - THE WEIGHTING OF THIS CRITERION IS LOW AVERAGE.	ASSESSMEN INFLUENCE INTRODUCE FACILITIE RECOGNIZE
11. LOGISTICS REQUIREMENTS	--	10	RATED HIGH - THE LOGISTIC CAPABILITY OF THE AIR FORCE IS LIMITED AND IN TIMES OF CONFLICT WILL BE TAXED TO THE MAXIMUM BY MULTISERVICE DEMANDS. LOW LOGISTICS REQUIREMENTS ARE HIGHLY DESIRABLE CHARACTERISTICS OF THE ARPV SYSTEM TO RANK AMONG THE PRIMARY FACTORS.	INCREASE RESULT OF WHICH SYS PORT REQU MENT - WH REQUIREME
12. FACILITY REQUIREMENTS	--	7	RATED MEDIUM/HIGH. AN IMPORTANT FACTOR IN DETERMINING SYSTEM SUITABILITY FOR INVENTORY ACQUISITION. CLOSELY ASSOCIATED WITH SYSTEM COST AND ABILITY OF DEPLOYMENT OF THE SYSTEM IN CERTAIN GEO/POLITICAL AREAS.	ASSESSMEN BUILDINGS ADOPTING
13. PECULIAR EQUIPMENT	AUXILIARY EQUIPMENT	7	RATED MEDIUM/HIGH. THIS RATING IS INTENDED TO EMPHASIZE THE DEGREE OF DEPARTURE FROM THE EXISTING AGE CONCEPTS AND EXTRA ENGINEERING EFFORT REQUIRED TO PUT THE SYSTEM INTO OPERATIONAL USE	ALL ITEMS EXISTING IN THE I CONSOLES SPECIFIC ETC.
14. VEHICLE WEIGHT CONTRIBUTION	RPV VOLUME/WEIGHT RANGE PENALTY	7	RATED MEDIUM/HIGH. THE WEIGHT OF L&R SYSTEM WHICH REMAINS ONBOARD DURING RPV MISSION IS AN IMPORTANT FACTOR AFFECTING VEHICLE PERFORMANCE AND VEHICLE/MISSION CAPABILITY.	WEIGHT/V OF THE S WEIGHT A

teria Definition (Cont'd)
nting Factors)

N CTOR	DEFINITION OF DESCRIPTOR
AN IMPORTANT WITH POWERFUL ND TIME.	ASSESSMENT OF ALL ASPECTS OF SYSTEM SET-UP, MOVEMENT, ALIGNMENT, TRANSPORTATION MOBILITY FROM ONE LOCATION TO ANOTHER, (WIND-DOWN) AND SERVICING OPERATIONS, INCLUDES NUMBER OF PERSONNEL REQUIRED, SKILL LEVELS, SPECIFIC TIE-UPS IN CONNECTION WITH SYSTEM TRANSPORTABILITY, LIFTING, TOWING, FLAT BED TRANSPORTING, CRANING AND UNDER OWN POWER CAPABILITY. ENGINE STARTING, TESTING AND ARMAMENT HANDLING.
AN IMPORTANT HICLE DESIGN. DE- E L&R SYSTEM IS TO AFFECT THE C CONFIGURATION SIZE AND POWER	THIS DESCRIPTOR ASSESSES THE IMPACT OF L&R SYSTEM ON THE POTENTIAL CONFIGURATION OF THE ARPV. THE VEHICLES AERODYNAMIC BODY WITH REQUIRED VOLUME, LIFT AND PERFORMANCE TO CARRY OUT ARPV MISSION MAY HAVE MANY SHAPES AND CONFIGURATIONS. WITHIN THESE POSSIBILITIES, HOWEVER, THE VEHICLE ITSELF MUST HAVE LOW DRAG, LOW RADAR CROSS-SECTION, LARGE C OF G MOVEMENT TOLERANCE, ABILITY TO ASSUME SUITABLE AND SAFE LAUNCH AND RECOVERY ATTITUDE, ABILITY TO ADAPT TO ACCEPT THE ASSESSED SYSTEM EITHER INTERNALLY OR EXTERNALLY IN TERMS OF VOLUME AND WEIGHT
THE L&R SYSTEMS E IMPACT ON TOTAL S UNDERSTOOD TODAY UMED COMPATIBLE THE STUDY. AS THE EPT A GREAT VARIETY E WEIGHTING OF THIS ERAGE.	ASSESSMENT TO WHAT DEGREE THE L&R CONCEPT UNDER ANALYSIS INFLUENCED THE EXISTING PRINCIPLES OF RPV OPERATIONS. WILL IT INTRODUCE NEW FUNCTIONS, NEW EQUIPMENTS, NEW SKILLS, NEW FACILITIES, OVER AND ABOVE THOSE ALREADY IN EXISTENCE OR RECOGNIZED AS THOSE REQUIRED.
GISTIC CAPABILITY LIMITED AND IN ILL BE TAXED TO ISERVICE DEMANDS. REMENTS ARE HIGHLY ISTICS OF THE ARPV G THE PRIMARY	INCREASE OR DECREASE OF LOGISTICS REQUIREMENT IS ASSESSED AS A RESULT OF ADOPTION OF THE CANDIDATE SYSTEM. THE STANDARD AGAINST WHICH SYSTEMS ARE ASSESSED IS THE PRESENT ESTIMATED LOGISTIC SUPPORT REQUIRED TO MOVE FIVE DRONES, WITH MOBILITY KITS AND EQUIPMENT - WHICH IS TWO C5A OR NINE C141 (THIS EXCLUDES LOGISTIC REQUIREMENTS FOR MOVEMENT OF MARS - HELICOPTERS)
AN IMPORTANT NG SYSTEM SUIT- RY ACQUISITION. WITH SYSTEM COST DYMENT OF THE SYS- POLITICAL AREAS.	ASSESSMENT OF SIZE OF OPERATING SITES, NEW LAY-OUTS, NEW BUILDINGS, NEW STORAGE AND MAINTENANCE SHOPS AS A RESULT OF ADOPTING A GIVEN L&R SYSTEM.
THIS RATING IS ZE THE DEGREE OF EXISTING AGE ENGINEERING PUT THE SYSTEM E	ALL ITEMS OF EQUIPMENT ARE CONSIDERED THAT ARE EXTRANEOUS TO THE EXISTING SUPPORT EQUIPMENT AND CANNOT BE USED BY ANY OTHER SYSTEM IN THE INVENTORY. ALL FORMS OF ADAPTERS, CHECK-OUT AND CONTROL CONSOLES, POWER CARTS, DOLLIES, SPECIFIC RECOVERY LIFTERS, SPECIFIC LAUNCH EQUIPMENTS SUCH AS WIRE GUIDES, STEERING TROUGHS, ETC.
THE WEIGHT OF MAINS ONBOARD IS AN IMPORTANT HICLE PERFORM- SSION CAPABILITY.	WEIGHT/VOLUME PENALTY IS ASSESSED THAT MAY RESULT FROM ADAPTATION OF THE SYSTEM. THE PRESENT PARACHUTE (MARS) RECOVERY SYSTEM WEIGHT AND VOLUME ARE USED AS BASIS OF WEIGHT/VOLUME COMPARISON.

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The next step in the procedure is to calculate the mean and the standard deviation of the FOMs. Those FOMs which are more than one standard deviation from the mean are considered to be better (or worse) that the rest. An example of the comparative histogram of individual FOMs with the mean and standard deviation boundaries for the lift systems in conventional take-off, is shown in Figure 2.2-4.

It can be seen that the acceptance level of the "own wing" is better while the "droppable extra wing" is worse than the rest of the proposed lift systems.

In the example shown several other systems are in the "grey" area and require additional trade-off analysis for final decisions.

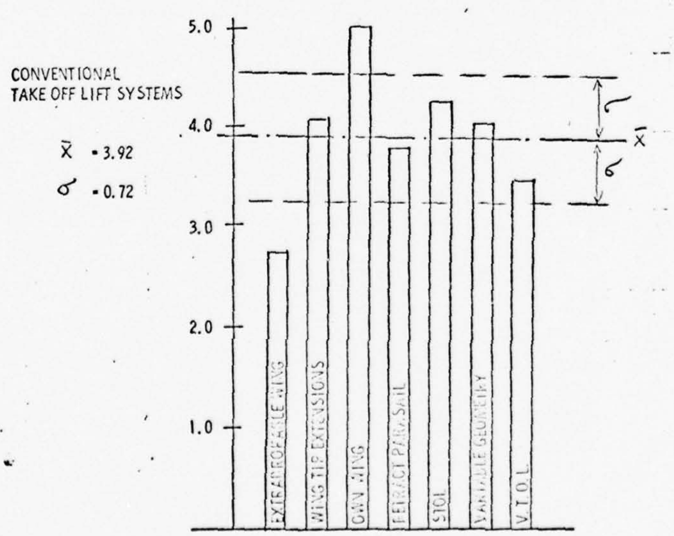

Figure 2.2-4. Histogram of Conventional Take-Off Lift Systems

3.0 DISCUSSION OF RESULTS

3.1 GENERAL CONSIDERATION

This section presents a summary review of the P.O.E.D. trade-off assessment of Launch and Recovery systems and presents results obtained.

Before proceeding with the evaluation of L&R elements, it was necessary to describe their configuration and characteristics adequately, yet briefly, so that in the assessment process their functional and operational aspects were similarily interpreted by those participating in the P.O.E.D. exercise. For this purpose a glossary of terms was developed for those elements of L&R which may not be readily obvious. This glossary is included in the Appendix (Pages A-11 to A-27).

As the assessment was to be kept free of bias - all systems were ranked "across the board laterally" rather than one at a time down the descriptor column.

When using the above method of comparison of the innovating schemes with the already existing systems, a judgment was made based on a realistic lay-out and, if necessary, a basic schematic of a new system. This approach identified the items in the new system and related them, where appropriate, to the functional and hardware aspects similar to the elements in the system in existance.

The original Launch and Recovery trade-off study using POED technique is contained in three Rockwell International Internal Letters: (1) ARPV No. 45-75, dtd 27 June 1975; (2) ARPV No. 46-75, dtd 28 June 1975; and (3) ARPV No. 82-75, dtd 11 August 1975. These were passed on to

the SPO monitor during TIM 1 and TIM 2 (Technical Interchange Meetings). Since that time, however, the progress in the system definition called for review and up-date of some of the potential systems. These up-dates are indicated whenever a reference is made to the original trade-study and a detailed change in descriptor rating discussed. The assessment sheets in the report show only the updated ratings and F.O.M. values.

3.2 ASSESSMENT SHEET #1 - CONVENTIONAL TAKE-OFF LIFT SYSTEM

In this trade study, seven lift systems, including STO and VTO, were assessed for a vehicle using conventional or unassisted take-off. Figure 3.2-1 shows the assessment sheet and the resulting histogram. Basic wing (O.W.) and STO concepts were rated highest while VTO and droppable wing were lowest. In all, the basic wing (own wing) concepts were allotted, one (1) <u>excellent</u> (risk) and seven (7) <u>very good</u> acceptance ratings. The low ratings were for survivability (on account of long take-off distances), flexibility - (because of poor adaptability to changing field requirements) and poor facilities rating. These last three characteristics were eventually the basic cause of this concept elimination when the field length requirements were exercised against the system. (See Section 4.3 .) The STO geometry was rated second in the original assessment showing strength in survivability, flexibility and launch rate and generally good average rating throughout.

The aerodynamic analyses of the wing geometry requirements indicated that adequate STO performance existed without need for internal blowing or complex cascaded airfoil design. Further, the modularity of the system was maintained by retention of symmetrical flip-over wing and a simple

A_j

SCALE OF ACCEPTANCE

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

W_i

OPERATIONAL WEIGHTING FACTORS

10.0 EXTREMELY IMPORTANT
7.0 IMPORTANT
5.0 AVERAGE EFFECT
3.0 LESS THAN AVERAGE EFFECT

CRITERIA	WEIGHT FACTOR	O.W. PLUS DROPPABLE WING	O.W. PLUS WING TIP EXTENSIONS	OWN WING (O.W.)	O.W. PLUS RETRACTABLE PARAFOIL	O.W. PLUS STOL (HIGH LIFT)	VARIABLE GEOMETRY WING	V.T.O.			A_j
COST	10.0	2/20	3/30	6/60	3/30	3/30	1.5/15	1/10			
COMPLEXITY	10.0	3/30	3/30	6/60	3/30	5/50	2/20	2/20			
SURVIVABILITY	10.0	5/50	5/50	3/30	5/50	6/60	4/40	2/20			
TECHNICAL RISK	5.0	3/15	4/20	7/35	3/15	4/20	2/10	2/10			
FLEXIBILITY	7.0	3/21	4/28	3/21	5/35	6/42	6/42	7/49			
LAUNCH RATE (RECOVERY RATE)	10.0	2/20	5/50	6/60	4/40	6/60	6/60	6/60			
AVAILABILITY	5.0	2/10	4/20	5/25	3/15	4/20	3/15	3/15			
HANDLING	7.0	2/14	3/21	6/42	3/21	4/28	4/28	3/21			
VEHICLE COMPATIBILITY	7.0	3/21	4/28	6/42	2/14	5/35	2/14	3/21			
SYSTEM COMPATIBILITY	5.0	2/10	3/15	6/30	5/25	4/20	4/20	5/25			
LOGISTICS REQUIREMENTS	10.0	1/10	2/20	5/50	3/30	4/40	3/30	3/30			
FACILITIES REQUIREMENTS	7.0	4/28	5/35	2/14	3/21	5/35	5/35	6/42			
PECULIAR EQUIPMENT	7.0	3/21	3/21	6/42	3/21	5/35	5/35	4/28			
VEHICLE WEIGHT CONTRIBUTION	7.0	3/21	5/35	4/28	3/21	5/35	2/14	2/14			
TOTAL	107.0	291	403	539	368	510	378	365			
FIGURE OF MERIT		2.71	3.76	5.03	3.43	4.76	3.53	3.41			
RANK NUMBER		7	3	1	5	2	4	6			

W_i

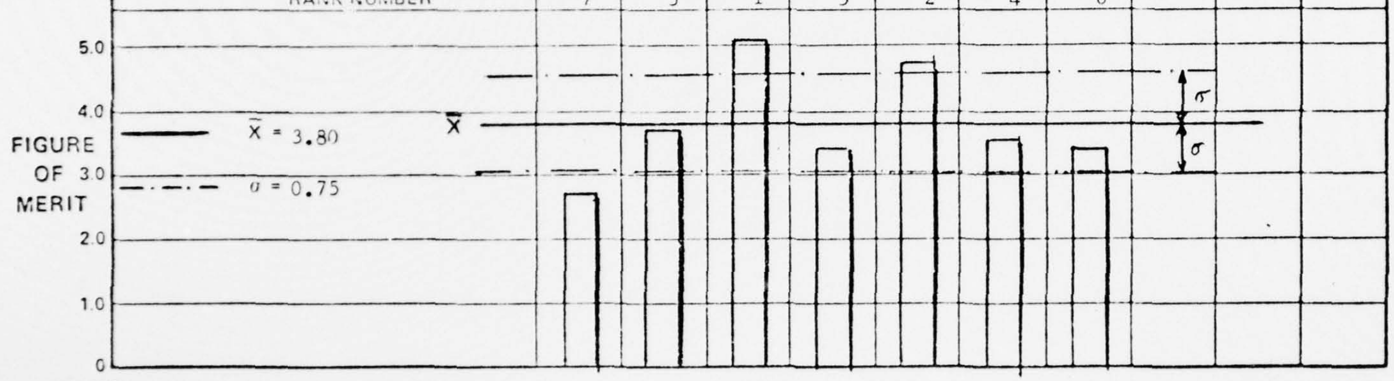

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Figure 3.2-1. Assessment Sheet #1 - Unassisted Conventional Take-Off Life Systems

screw jack design for simultaneous operation of leading and trailing edge flaps. This resulted in upgrading the complexity, weight contribution and vehicle compatibility ratings. While the STO rank number did not change (#2), its figure of merit (F.O.M.) increased as a result of these changes from F.O.M. = 4.31 shown in original reports to FOM = 4.76 shown here.

The next in order of acceptance was the Wing Tip Extensions concept. Basically, the objective here was to shorten the take-off run and remove the excess weight of a longer wing, not essential for the mission phase. Upon more detailed analysis, it became apparent that the wing tip additions were to represent up to 50 percent of nominal mission wing area in order to be effective. This in turn, drove up the cost and the associated complexity also handling and maintenance aspects were adversely affected. The facilities requirements rating was brought to the level of STO (Rating 5.0) as it was considered that the take-off performance of the two systems was comparable.

The variable geometry wings, retractable parafoil wing and the VTO systems came well behind the first three candidates, and there appears to be very little difference in their overall rating. The primary concern was their cost and complexity with low logistic rating. The vehicle compatibility was also assessed low as none of these systems lends itself to major parts interchangeability or modular approach. The case of the retractable parafoil wing required a new concept of the wing with flexible, retractable survaces, capable of handling span loading of up to 375 lbs per foot. Finally, the droppable wing concept with 12 ratings at or below level of "less than average" showed least promise in its application.

In the unassisted launch category, the initial candidates were, therefore,

1. Basic wing (own wing)
2. STO - High Lift Wing (without blowing)
3. Basic Wing with droppable tip extensions

3.3 ASSESSMENT SHEET #2 - CONVENTIONAL LANDING - LIFT SYSTEMS

In this group the STOL (high lift wing) was rated best showning a good average rating throughout. The basic wing configuration was next. At this stage of the assessment the system need for the arrester gear or the microwave approach and landing was not as yet obvious, therefore, the concepts assumed conventional approach, touchdown and run-out to a stop after landing. The important performance considerations such as landing distances, dispersion at impact, glide path angle, touchdown velocities with associated kinetic energy content were all considered within the descriptor criteria such as survivability, handling and facilities requirements. (See Appendix Pages A-29 to A-31. The concepts employing flexible surface wing devices such as parasail, flexible wing (Rogallo) and parafoil, showed poor ratings in vehicle compatibility (stowage, deployment), logistics, vehicle weight contribution and handling; and were considered impractical for a system with a high rate, multiple mission sortie operation.

The variable geometry wing with its cost, complexity and the impact on vehicle design such as large weight contribution, lack of modularity and a complex store suspension system did not come through as a viable concept.

Figure 3.3-1 shows the assessment sheet and the histogram of the P.O.F.D. rating in this group.

SCALE OF ACCEPTANCE (A_j)

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

OPERATIONAL WEIGHTING FACTORS (W_i)

10.0 EXTREMELY IMPORTANT
7.0 IMPORTANT
5.0 AVERAGE EFFECT
3.0 LESS THAN AVERAGE EFFECT

CRITERIA (W_i)	WEIGHT FACTOR	VARIABLE GEOMETRY WING	STOL GEOMETRY WING	O.W. PLUS RETRACTABLE PARAFOIL	BASIC WING (O.W.)	O.W. PLUS PARASAIL	O.W. PLUS FLEXIBLE WING				
COST	10.0	2.0/20	4.0/40	3.0/30	6.0/60	3.5/35	3.0/30				
COMPLEXITY	10.0	2.0/20	5.0/50	3.0/30	6.0/60	3.0/30	3.0/20				
SURVIVABILITY	10.0	5.5/55	5.0/50	4.5/45	2.5/25	4.5/45	4.5/45				
TECHNICAL RISK	5.0	3.0/15	4.0/20	3.0/15	6.0/30	2.0/10	1.5/7.5				
FLEXIBILITY	7.0	4.5/31.5	4.5/31.5	3.5/24.5	2.0/14	3.0/21	3.0/21				
LAUNCH RATE (RECOVERY RATE)	10.0	4.0/40	4.0/40	4.0/40	3.0/30	3.5/35	4.0/40				
AVAILABILITY	5.0	5.0/25	5.0/25	3.5/17.5	5.0/25	3.0/15	2.0/10				
HANDLING	7.0	5.0/35	5.0/35	4.5/31.5	5.0/35	2.0/14	2.0/14				
VEHICLE COMPATIBILITY	7.0	2.0/14	5.0/35	3.0/21	4.0/28	2.0/14	1.0/7				
SYSTEM COMPATIBILITY	5.0	5.0/25	5.0/25	5.0/25	5.0/25	5.0/25	3.0/15				
LOGISTICS REQUIREMENTS	10.0	3.0/30	3.5/35	3.0/30	5.0/50	2.0/20	1.5/15				
FACILITIES REQUIREMENTS	7.0	5.0/35	5.0/35	4.0/28	4.0/28	4.0/28	4.0/28				
PECULIAR EQUIPMENT	7.0	4.0/28	4.0/28	3.0/21	4.0/28	2.0/14	2.0/14				
VEHICLE WEIGHT CONTRIBUTION	7.0	2.5/17.5	3.0/21	3.0/21	3.0/21	2.5/17.5	2.0/14				
TOTAL	107.0	391.0	470.5	379.5	459.0	323.5	280.5				
FIGURE OF MERIT		3.65	4.39	3.54	4.28	3.02	2.62				
RANK NUMBER		3	1	4	2	5	6				

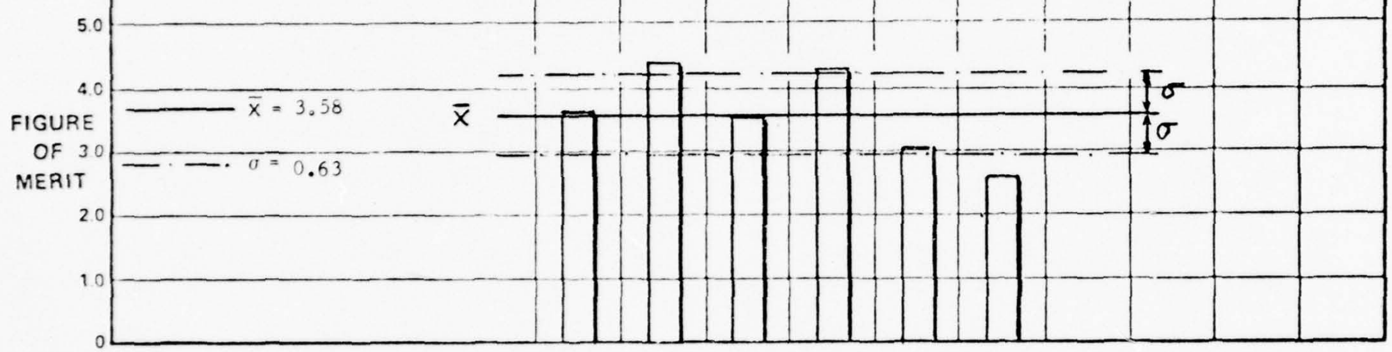

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Figure 3.3-1. Assessment Sheet #2 - Conventional Landing Lift Systems

3.4 ASSESSMENT SHEET #3 - ASSISTED TAKE-OFF SYSTEMS

Within this group ten systems were assessed. Two were the air launched systems, two were catapults, two - power sleds, three - rocket assists and one hybrid catapult system. The glossary section in the Appendix gives the description of each of the candidates. Figure3.4-1 presents the resulting assessment and histogram. It should be noted at this point that the original assessment was conducted at the onset of the study when the mission impact on the vehicle requirements was not fully understood; hence the vehicle weight and size requirements to handle the mission payloads was under-estimated. This was the principal reason for the hybrid truck catapult system to score so well in the ratings. It offered many features that were beneficial to ARPV operation,such as excellent flexibility with no need for new facilities. It showed a very good system compatibility and minimum contribution to vehicle weight particularly if the need for a landing gear could be obviated.

Later in the study when the required mission range and payload were established and the size of the vehicle more clearly defined, it was apparent that problems would arise in handling 6000-7000 lbs. vehicle in an overhead rail launching system as defined by hybrid truck launcher concept. For this new vehicle weight range, the points were lost in cost, complexity, technical risk, and logistics reducing the F.O.M. from 4.48 to 4.08. This new value, however, still retained the Hybrid Truck Launcher Concept (two trucks) as the best ground launch assist system.

With the exception of Rail Catapult, which came close second, all the others assisted take-off systems ranked quite evenly having their

A_j

SCALE OF ACCEPTANCE

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

W_i

OPERATIONAL WEIGHTING FACTORS

10.0 EXTREMELY IMPORTANT
7.0 IMPORTANT
5.0 AVERAGE EFFECT
3.0 LESS THAN AVERAGE EFFECT

CRITERIA (W_i)	WEIGHT FACTOR	AIR LAUNCH: AIRCRAFT REMOTE	AIR LAUNCH: MOTHER AIRCRAFT	THRUST SLEDS: OBSOLETE AIRFRAMES	THRUST SLEDS: POWERED SLEDS	CATAPULTS: RUNWAY	CATAPULTS: RAIL	CATAPULTS: HYBRID TRUCKS	RATO: INTERNAL RATO	RATO: ZERO LENGTH RATO	RATO: EXTERNAL JATO
COST	10.0	2.5/25	1.0/10	3.5/35	2.0/20	2.5/25	3.0/30	2.0/20	4.0/40	2.5/25	3.5/35
COMPLEXITY	10.0	4.0/40	2.0/20	3.0/30	3.0/30	3.0/30	3.0/30	2.0/20	4.5/45	2.5/25	4.0/40
SURVIVABILITY	10.0	5.0/50	3.0/30	3.0/30	4.0/40	4.5/45	5.0/50	5.5/55	3.0/30	5.0/50	4.0/40
TECHNICAL RISK	5.0	6.5/32.5	2.0/10	4.0/20	3.5/17.5	4.0/20	3.5/17.5	2.0/10	4.0/20	4.0/20	4.0/20
FLEXIBILITY	7.0	4.0/28	4.0/28	4.0/28	4.0/28	3.0/21	2.5/17.5	7.0/49	3.0/21	5.5/38.5	3.0/21
LAUNCH RATE (RECOVERY RATE)	10.0	1.0/10	3.0/30	3.0/30	3.5/35	5.0/50	5.0/50	3.5/35	4.0/40	4.0/40	2.5/25
AVAILABILITY	5.0	2.0/10	2.0/10	2.0/10	2.0/10	4.0/20	3.5/17.5	4.0/20	3.0/15	4.0/20	2.5/12.5
HANDLING	7.0	2.5/17.5	1.0/7	1.0/7	2.0/14	3.0/21	3.0/21	3.5/24.5	4.5/31.5	4.0/28	3.0/21
VEHICLE COMPATIBILITY	7.0	4.0/28	4.0/28	3.0/21	3.0/21	3.5/24.5	3.5/24.5	3.0/21	2.5/17.5	3.0/21	4.0/28
SYSTEM COMPATIBILITY	5.0	5.0/25	5.0/25	5.0/25	5.0/25	5.0/25	5.0/25	6.0/30	5.0/25	5.0/25	5.0/25
LOGISTICS REQUIREMENTS	10.0	3.5/35	3.0/30	3.0/30	3.0/30	2.0/20	2.0/20	3.0/30	3.0/30	2.0/20	2.5/25
FACILITIES REQUIREMENTS	7.0	2.0/14	1.5/10.5	6.0/42	6.0/42	4.0/28	6.0/42	7.0/49	4.5/31.5	6.0/42	4.0/28
PECULIAR EQUIPMENT	7.0	3.0/21	3.0/21	4.0/28	3.5/24.5	3.0/21	4.0/28	4.0/28	3.0/21	3.0/21	3.0/21
VEHICLE WEIGHT CONTRIBUTION	7.0	6.0/42	3.0/21	6.0/42	6.0/42	5.0/35	6.0/42	6.0/42	1.0/7	5.0/35	5.0/35
TOTAL	107.0	378	280.5	378	379	385.5	415	433.5	374.5	410.5	376.5
FIGURE OF MERIT		3.53	2.62	3.53	3.54	3.60	3.87	4.05	3.50	3.83	3.51
RANK NUMBER		6/7	10	7/6	5	4	2	1	9	3	8

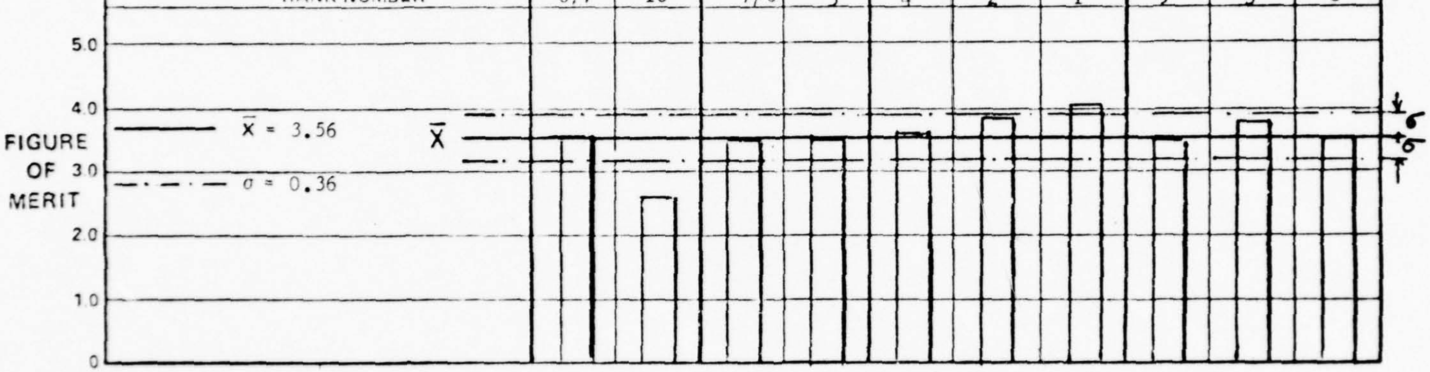

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Figure 3.4-1. Assessment Sheet #3 - Assisted Take-Off Systems

respective strength or weaknesses in different parts of the descriptor spectrum. In all, only the H.T.L. & Rail Catapul were ranked average, the remainder being between less than the average and the average rating.

The air launched systems were rated very low; their weak points being cost, launch rate, availability, facilities and logistics associated with the operation of launch aircraft. The mothership concept, in addition, was low in survivability, indicated poor technical risk (wing folding) and difficult system handling, both, on the ground and in the air.

The catapults were relatively high on the rating scale, their principal shortcomings being cost, lack of flexibility (mobility) and vehicle handling problems. In the case of runway catapult (SATS Catapult), the logistic support needed for system transfer from one location to another was considered high.

From the rocket assisted launch systems - the zero length launcher with a RATO TVC rated third among all systems, the external and integral JATO/RATO being rated 7 and 9 respectively. The ZEL with TVC is costly, but it makes out in survivability, flexibility and relatively simple facilities. Its ability to control thrust vector to maintain the required flight path and flight attitude during launch and relatively small weight contribution to the mission itself (system assumed no landing gear) were the contributing factors to this high rating. The detrimental features were: complexity, cost and logistics requirements.

3.5 ASSESSMENT SHEET #4 - INTEGRATED VERTICAL (OR NEAR VERTICAL) RECOVERY SYSTEMS

Although the two main characteristics in the title are common to all seven system concepts, the approach to their technical solutions is quite different. The VTOL concept (only augmentor wing design was considered here) has the power plant integrated with the vehicle, and is the only one system that can regulate the descent/ascent rates as required. The foldable rotor concept could regulate its descent rates by change in the collective pitch of the blades in autorotation and so affect the impact velocity. The other five are basically the steady descent rate systems that are designed at the onset. Out of the group, the VTOL, the steerable flexible wing, parawing and the rotor system can offset the wind effects by control of descent towards the wind. The other three (parachute, paracone and balloon) float down with the wind. The impact dispersion will depend on ability to orient and react against the wind vector. Figure 3.5-1 presents the assessment sheet with its ranking histogram. The assessment of these modes of recovery assigns highest rating to a dual mode parachute, a well proven system in the RPV field.

It scores better than average in 8 out of 14 descriptors, the system cost, the vehicle survivability and mission weight contribution being the main adverse characteristics. The powered vertical landing system (VTOL) was rated second. It rated low in cost and complexity, but had high scores in logistics, facilities and overall system flexibility.

The steerable flex wing (Rogallo) and a parawing were next, their dispersion controllability feature having strong effect on that rating. The integral paracone and the balloon concepts were invalidated as potential recovery systems because of their vehicle incompatibility ratings (rated 0 - zero).

A_j

SCALE OF ACCEPTANCE

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

W_i

OPERATIONAL WEIGHTING FACTORS

10.0 EXTREMELY IMPORTANT
7.0 IMPORTANT
5.0 AVERAGE EFFECT
3.0 LESS THAN AVERAGE EFFECT

A_j

CRITERIA (W_i)	WEIGHT FACTOR	FOLDABLE ROTOR	INTEGRAL BALLOON	VTOL	INTEGRAL DUAL MODE MARS & PARA	INTEGRAL PARACONE	STEERABLE FLEXIBLE WING	PARAWING			
COST	10.0	3.0/30	3.5/35	2.0/20	3.0/30	2.5/25	3.5/35	3.5/35			
COMPLEXITY	10.0	2.5/25	3.0/30	2.5/25	5.5/55	2.5/25	3.0/30	3.0/30			
SURVIVABILITY	10.0	4.0/40	4.0/40	4.0/40	3.0/30	4.5/45	4.0/40	4.5/45			
TECHNICAL RISK	5.0	3.0/15	3.0/15	4.0/20	7.0/35	2.5/12.5	3.0/15	4.0/20			
FLEXIBILITY	7.0	4.0/28	4.0/28	7.0/49	4.5/31.5	6.0/42	6.0/42	5.5/38.5			
LAUNCH RATE (RECOVERY RATE)	10.0	3.0/30	2.5/21.5	4.0/40	5.5/55	3.5/35	3.5/35	3.5/35			
AVAILABILITY	5.0	3.0/15	2.0/10	3.5/17.5	5.0/25	2.0/10	3.0/15	2.0/10			
HANDLING	7.0	3.5/22.5	1.0/7	4.0/28	3.5/24.5	2.5/17.5	2.5/17.5	2.0/14			
VEHICLE COMPATIBILITY	7.0	1.5/10.5	0/0	4.0/28	4.0/28	0/0	2.0/14	3.0/21			
SYSTEM COMPATIBILITY	5.0	3.5/17.5	2.5/12.5	5.0/25	4.0/20	3.0/15	4.0/20	4.5/22.5			
LOGISTICS REQUIREMENTS	10.0	3.0/30	1.5/15	6.0/60	3.5/35	3.0/30	3.5/35	3.5/35			
FACILITIES REQUIREMENTS	7.0	4.0/28	4.5/31.5	6.0/42	4.5/31.5	4.5/31.5	5.0/35	5.0/35			
PECULIAR EQUIPMENT	7.0	3.0/21	2.0/14	4.0/28	4.0/28	2.0/14	2.0/14	4.0/28			
VEHICLE WEIGHT CONTRIBUTION	7.0	2.5/17.5	2.0/14	3.0/21	3.0/21	2.0/14	2.5/17.5	3.0/21			
TOTAL	107.0	330.0	277	443.5	449.5	316.5	365	390			
FIGURE OF MERIT		3.08	2.58	4.14	4.20	2.95	3.41	3.64			
RANK NUMBER		5	INV	2	1	INV	4	3			

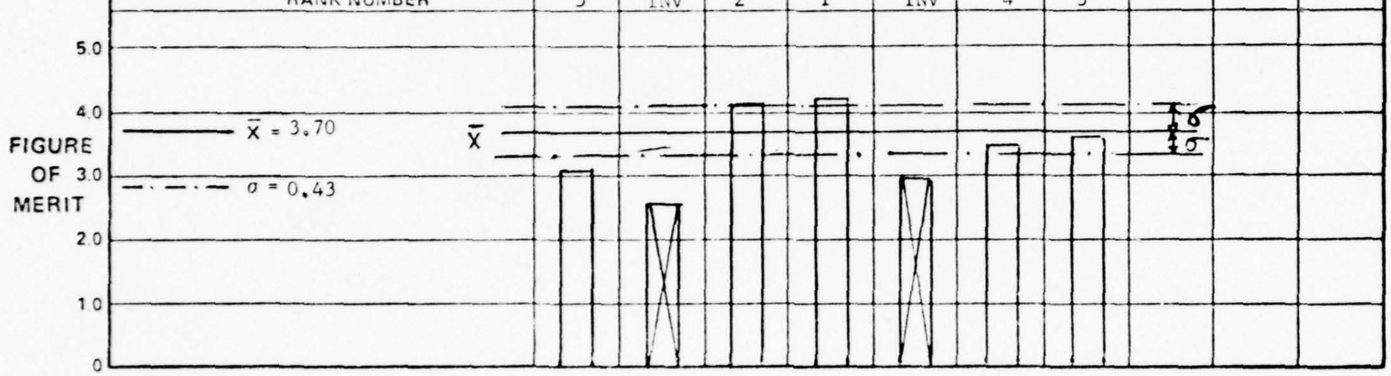

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Figure 3.5-1. Assessment Sheet #4 - Integral Verical Revocery Systems

The foldable rotor system appeared much more feasible except for problems in packaging (vehicle compatibilities), system complexity and weight contribution.

Each of the vertical recovery systems, with the exception of (VTOL) vertical powered landing system would have to have some form of impact attenuating device, to absorb the vertical and/or horizontal velocity impact. These interface systems were discussed under Parachute Recovery Interface Systems (Assessment Sheet #8), and most of them can combine with the basic recovery system discussed in this section.

3.6 ASSESSMENT SHEET #5 - EXTERNAL RECOVERY SYSTEM

In the type of recovery discussed in this section, the vehicle in either active or passive role intercepts the recovery system in flight, is brought to a stop relative to the system and eventually is deposited by one means or another on the ground. The group contains 3 innovating concepts: the MITT (Mid-Air Intercept of Terminal Trajectory); the Paracatch; and the High-line Arrest System. The initial assessment, both MITT and Paracatch showed strength as potentially suitable recovery systems, both employing the bouyancy of helium balloons for system vertical deployment and partially for vehicle arrestment from low speed flight. The subsequent investigation with participating balloon vendors indicated areas of potential problems in handling helium balloons in the field, a big logistic train associated with overseas maintenance of the system and finally high operating cost. Upon reassessment of the ratings in the areas indicated, these two systems still emerged as the leaders in the group, however, with overall rating "less than average".

The MARS Helicopters Recovery rated third. The mothership concept did not rate well as it was deficient in many areas in the tactical field. Its high cost, poor survivability in European conflict environment, poor launch rate, and RPV handling on recovery, as well as technical risk associated with an unmanned system in the proximity of a large aircraft all point to a low acceptability rating. The reassessment of the ratings in the light of new data from vendors, upgraded the potential of a fixed aircraft MARS over the High Line Arrest System. The latter was considered lacking in flexibility, demanding of fairly large facility, both costly and complex. The major problem in the fixed aircraft MARS system is the problem (this also being true of the mothership) of stowage (or retention of the vehicle) for landing of the recovery aircraft. This forces the ARPV wing designs into foldable configurations with associated complexity and cost. The detailed assessment sheet and the histogram of these six system concepts is shown in Figure 3.6-1. Their descriptive data is contained in the Glossary of Terms.

3.7 ASSESSMENT SHEET #6 - CONVENTIONAL TAKE-OFF SURFACE INTERFACE SYSTEMS

The next step in the Launch and Recovery POED assessment was the definition and ranking of the interface systems between the vehicle and the launch or recovery surface. In some specific cases another element is interposed between them. In the launch case this is a launch assist, and in the recovery case a retardation or energy absorbing element (see Figure 3.7-1).

In the conventional take-off, nine interface systems were considered: five employing wheels, including two types of wheel dollies, two using air cushion gear and one using skids only. On take-off from water, a float/dolly system was also evaluated against the air cushion system. On launch from

A_j

SCALE OF ACCEPTANCE

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

W_i

OPERATIONAL WEIGHTING FACTORS

10.0	EXTREMELY IMPORTANT
7.0	IMPORTANT
5.0	AVERAGE EFFECT
3.0	LESS THAN AVERAGE EFFECT

A_j

CRITERIA (W_i)	WEIGHT FACTOR	MOTHER AIRCRAFT	MIFF	PARACATCH	MARS HELICOPTER	MARS FIXED WING	HIGH LINE ARREST.				
COST	10.0	1.0/10	2.0/20	3.0/30	2.0/20	2.0/20	2.0/20				
COMPLEXITY	10.0	2.0/20	2.5/25	3.0/30	5.0/50	4.0/40	2.0/20				
SURVIVABILITY	10.0	2.0/20	5.5/55	5.5/55	3.0/30	2.5/25	3.0/30				
TECHNICAL RISK	5.0	2.0/10	2.5/12.5	3.0/15	5.0/25	4.0/20	3.0/15				
FLEXIBILITY	7.0	5.0/35	3.5/24.5	3.5/24.5	3.0/21	2.5/17.5	2.0/14				
LAUNCH RATE (RECOVERY RATE)	10.0	1.0/10	4.0/40	4.0/40	1.0/10	1.0/10	2.0/20				
AVAILABILITY	5.0	2.0/10	3.0/15	3.0/15	3.0/15	3.0/15	3.5/17.5				
HANDLING	7.0	1.0/7	2.0/14	3.0/21	4.0/28	2.5/17.5	3.0/21				
VEHICLE COMPATIBILITY	7.0	1.0/7	6.5/45.5	3.0/21	4.0/28	1.0/7	3.5/24.5				
SYSTEM COMPATIBILITY	5.0	5.0/25	3.0/15	4.0/20	5.0/25	4.0/20	2.0/10				
LOGISTICS REQUIREMENTS	10.0	2.5/25	1.0/10	1.5/15	3.0/30	3.5/35	3.0/30				
FACILITIES REQUIREMENTS	7.0	3.0/21	6.5/45.5	6.5/45.5	4.0/28	3.0/21	2.0/14				
PECULIAR EQUIPMENT	7.0	3.0/21	3.0/21	4.5/31.5	4.0/28	4.0/28	3.5/24.5				
VEHICLE WEIGHT CONTRIBUTION	7.0	4.0/28	6.5/45.5	6.0/42	3.5/24.5	3.5/24.5	4.5/31.5				
TOTAL	107.0	249.0	388.5	405.5	362.5	300.5	292.0				
FIGURE OF MERIT		2.32	3.63	3.78	3.38	2.80	2.72				
RANK NUMBER		6	2	1	3	4	5				

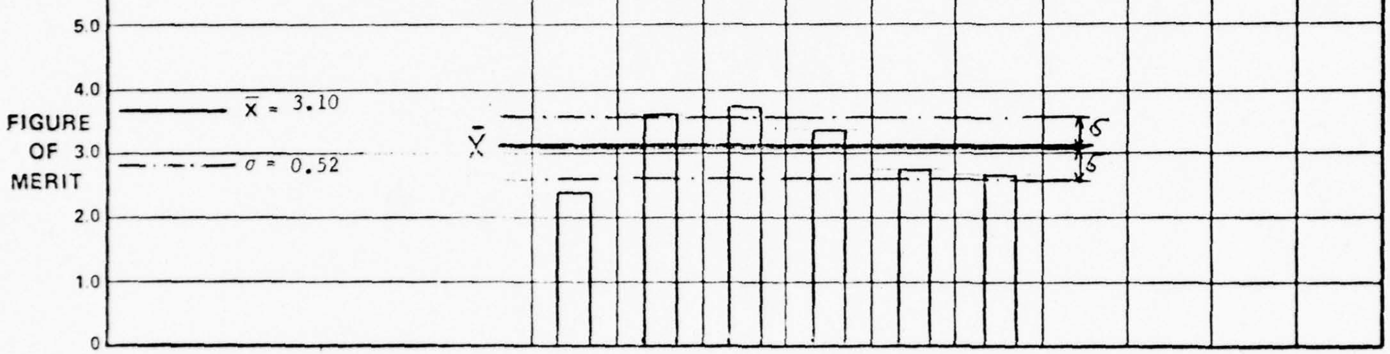

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Figure 3.6-1. Assessment Sheet #5 - External Recovery Systems

A_j

SCALE OF ACCEPTANCE

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

W_i

OPERATIONAL WEIGHTING FACTORS

10.0 EXTREMELY IMPORTANT
7.0 IMPORTANT
5.0 AVERAGE EFFECT
3.0 LESS THAN AVERAGE EFFECT

A_j

CRITERIA (W_i)	WEIGHT FACTOR	3 WHEEL DOLLY STEERABLE	EXTERNAL AIR CUSHION DOLLY	INTEGRAL AIR CUSHION GEAR	WHEELS RETRACTABLE	WHEELED DOLLY DROPPABLE	COMBO WHEELS/ SKIDS	SKIDS ONLY	DROPPABLE WHEELS		
COST	10.0	2.0/20	4.0/40	4.0/40	3.0/30	4.0/40	2.0/20	5.0/50	3.0/30		
COMPLEXITY	10.0	3.0/30	2.0/20	2.0/20	4.0/40	5.0/50	1.5/15	4.0/40	2.5/25		
SURVIVABILITY	10.0	4.0/40	4.0/40	4.0/40	6.0/60	5.0/50	5.0/50	2.0/20	5.0/50		
TECHNICAL RISK	5.0	4.0/20	3.0/15	2.0/10	7.0/35	5.0/25	3.0/15	4.0/20	3.0/15		
FLEXIBILITY	7.0	4.0/28	4.0/28	4.0/28	4.0/28	3.0/21	4.0/28	2.0/14	3.0/21		
LAUNCH RATE (RECOVERY RATE)	10.0	3.5/35	2.0/20	3.0/30	5.0/50	4.0/40	5.0/50	2.0/20	5.0/50		
AVAILABILITY	5.0	4.0/20	3.0/15	3.0/15	6.0/30	5.0/25	4.0/20	5.0/25	4.0/20		
HANDLING	7.0	3.0/21	2.0/14	3.0/21	6.0/42	6.0/42	5.0/35	1.0/7	6.0/42		
VEHICLE COMPATIBILITY	7.0	4.0/28	2.0/14	2.0/14	5.0/35	6.0/42	3.0/21	3.0/21	5.0/35		
SYSTEM COMPATIBILITY	5.0	3.0/15	5.0/25	5.0/25	5.0/25	3.0/15	4.0/20	2.0/10	2.0/10		
LOGISTICS REQUIREMENTS	10.0	4.0/40	3.0/30	4.0/40	6.0/60	4.0/40	3.5/35	4.0/40	3.0/30		
FACILITIES REQUIREMENTS	7.0	3.0/21	4.0/28	4.0/28	3.0/21	3.0/21	3.0/21	2.0/14	3.0/21		
PECULIAR EQUIPMENT	7.0	4.0/28	2.0/14	2.0/14	6.0/42	3.0/21	4.0/28	2.0/14	4.0/28		
VEHICLE WEIGHT CONTRIBUTION	7.0	6.0/42	4.0/28	3.0/21	3.0/21	6.0/42	2.0/14	3.0/21	5.0/35		
TOTAL	107.0	388	331	346	519	474	372	316	412		
FIGURE OF MERIT		3.62	3.09	3.23	4.85	4.42	3.47	2.95	3.85		
RANK NUMBER		4	7	6	1	2	5	8	3		

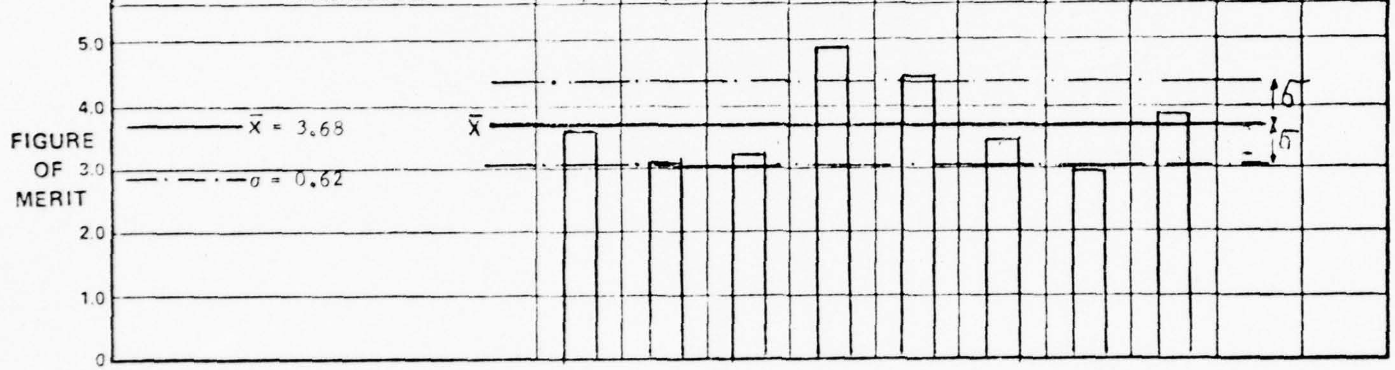

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Figure 3.7-1. Assessment Sheet #6 - Conventional Take-Off-Surface Interface Systems

snow, both air cushion landing gear and combined wheels/skis are compared. This rating is presented under the section Water/Snow Assessment (page 3-20).

The retractable conventional wheels were rated well ahead of the field having six descriptors in very good category. The primary advantages were in low technical risk, very good availability, instant mobility and ease of handling. They come internally with the vehicle, therefore, they do not increase the logistics volume requirement, and their demand for peculiar equipment is minimal. Their flexibility in actual operations has been demonstrated amply in the past. The main drawbacks were contribution to vehicle mission weight and more than average cost.

The droppable wheeled dolly was rated second. The concept that was assessed here was that similar to the one shown in the Appendix, Page A-40 which combined a two-wheeled dolly attached to a retractable skid located centrally in the fuselage. In this system, the vehicle actually leaves the ground in the tail down attitude with the dolly attached. The drop is affected immediately after take-off. Normally after two or three bounces, the dolly comes to rest generally undamaged as its low pressure tires absorb the impact energy. It has to be recovered by ground crews for further use. A steerable three-wheel dolly (wire or signal) has rated third, the concept being similar to that used in the Australian Jindivik Drone System. Among operational problems connected with dollies, is the inability to divorce the RPV from a lift or crane and a static stand on which the vehicle has to spend most of its time when it is not actually in transit on a dolly. All the complications associated with handling, transfer and recovery of the dolly add substantially to manpower and equipment,

as well as the operational turn around time, and can become critical when high launch rates are demanded. A detailed trade-off between a conventional three-cycle gear and a tricycle steerable dolly is given in Table 6.2-1 and Table 6.2-2, "Operational Assessment" under respective concepts evaluation.

The Combo wheels/skids concept for launch purposes is similar to the basic three-wheel gear. By combining the recovery function (large contact area - skids) with a launch function (wheels) the objective was to optimize both; but the added cost, complexity and the contribution to vehicle weight seem to negate the possible advantages that might be derived from this system. In the final analysis it was ranked lower than either of the wheeled dollies.

The air cushion systems evaluated for take-off comprised two basic approaches: (a) the external droppable, nonelastic air-cushion dolly and (b) the integral elastic, fully retractable, air cushion trunk system. The first of the two represents the approach similar to AFFDL experimental system in the Jindivik drone, the other being on the lines of Bell peripheral bag trunk concept similar to the type used on LA-4 and the Buffalo.

The ACLS (Air Cushion Landing System) overall assessment in its application to the ARPV concept was rated generally low on account of system inherent complexity, poor ground handling characteristics, excessive reliance on support equipment and technical risk. Detailed utility analysis results of the ACLS in ARPV application are given in the Appendix, Pages A-49 to A-51. The integral ACLS rated higher than the droppable dolly on account of expected better handling and lower logistics requirements.

In the droppable wheel concept, the objective is to have the benefits of wide track, low pressure gear during ground handling and take-off and by dropping the wheels - avoid the necessity of providing high volume stowage and extra weight and drag during the mission. The individual wheels on impacting the ground after drop are expected to have low incidence of damage. The shock absorbing and retracting system for each strut - would still be provided. The relatively high rating of this system resulted from the fact that it displayed a number of advantageous characteristics such as good handling, launch rate, survivability and weight reduction. Its drawbacks were related to system complexity and complications relating to wheels nonpermanence, recovery and reconditioning after use.

The skids alone were rated a poor take-off interface, although they are extensively used in the glider field. An excessive contact friction and resultant long take-off distances were considered to be the principal problems.

For the operation from water and snow,using ACLS or specifically designed equipment such as floats or skis, was a subject of a separate trade-off analysis - shown in Assessment Sheet #6a below. It should be noted that operating on ACLS from water, the vehicle must possess inherent buoyancy to prevent the loss of RPV upon damage to the ACLS. While it is conceded that as long as the air flow is provided to the ACLS - the system can tolerate fairly large perforations without loss of performance, once however, the supply of air ceases - the vehicle depends entirely on the integrity of the internal parking trunk for its support on water. Should this develop a slow leak, the vehicle having no natural buoyancy will sink, with all the attendant complications. A buoyant RPV was therefore assumed in this assessment.

These characteristics are reflected in the cost, complexity and vehicle compatibility descriptors. They result in a significant enhancement of vehicle survivability and system compatibility.

If the systems are confined entirely to water operation, then their respective ratings are quite similar. The advantage of ACLS would be distinct in an amphibious capability, provided it can negotiate the "transition belt" which normally exists between land and water without special site preparation. It should be noted that the winter operation from unfrozen lakes - at freezing temperatures - will be impossible in both modes because of the rapid build-up of the freezing spray on wings and control surfaces.

The operation over a deep snow surface will not be typical in the European scenario when operating from dedicated RPV bases. It is expected that the accumulation of snow in excess of 4-6 inches would have to be cleared from the flight areas - or otherwise, on thaw - refreeze cycle, the movement of men and vehicular transport would be seriously affected. In the unlikelyhood of having to maintain an operation over deep-fresh snow the vehicle would have to be equipped with a ski kit or ACLS. The assessment of these two systems in snow environment is based on the experiments and test data on air cushion vehicles performed in Canada - Reference*- and ski-equipped QV-1 Mohawk aircraft Reference ** , where it was noted that a 15,000 lbs ski equipped Mohawk will operate safely from all types of snow in depths varying from 4 to 60 inches.

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* ACV ICING PROBLEMS C.A. & S.J. DEC. 1973

** FLIGHT TESTS OF SKI EQUIPPED MOHAWK, C.A. & S.J. JAN. 1974

Assessment Sheet #6(a) in Figure 3.7-2, shows the comparative ratings between these two systems. In the overall rating, the ACLS was rated ahead of the ski equipped systems. It rated better in several aspects - such as survivability, flexibility and cost. The technical risk, handling and peculiar equipment were all rated low in the ACLS because: a) there is no easy solution to ACLS ground freezing on shut-down of the air supply; (b) In the ARPV the ACLS requires capability of side force generation for controlled movement across deep snow by remote means and (c) a mobile air supply generator is needed for vehicle mobility following engine shut-down.

The skis system would have to be an add-on kit designed so that its integration with the vehicle does not detract from vehicle performance. Here again a remote ground control capability is required with attendant high technical risk.

In all cases the ground vehicles and personnel directly in support of the ARPVs would acquire high levels of snow mobility.

SCALE OF ACCEPTANCE (A_j)

7.0	EXCELLENT	3.0	LESS THAN AVERACE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

OPERATIONAL WEIGHTING FACTORS (W_i)

10.0 EXTREMELY IMPORTANT
7.0 IMPORTANT
5.0 AVERAGE EFFECT
3.0 LESS THAN AVERAGE EFFECT

CRITERIA (W_i)	WEIGHT FACTOR	WATER: INTEGRAL AIR CUSHION	WATER: FLOATS INTEGRAL RETRACTABLE	SNOW: INTEGRAL AIR CUSHION	SNOW: WHEELS PLUS SKIS RETRACTABLE
COST	10.0	3.0/30	3.0/30	4.0/40	3.0/30
COMPLEXITY	10.0	2.0/20	1.5/15	3.0/30	3.0/30
SURVIVABILITY	10.0	5.0/50	4.0/40	5.0/50	4.0/40
TECHNICAL RISK	5.0	2.0/10	2.0/10	2.0/10	2.0/10
FLEXIBILITY	7.0	6.0/42	3.0/21	4.0/28	3.0/21
LAUNCH RATE (RECOVERY RATE)	10.0	3.0/30	3.0/30	4.0/40	4.0/40
AVAILABILITY	5.0	3.0/15	5.0/25	3.0/15	4.0/20
HANDLING	7.0	3.0/21	4.0/28	2.0/14	3.0/21
VEHICLE COMPATIBILITY	7.0	2.0/14	3.0/21	3.0/21	3.0/21
SYSTEM COMPATIBILITY	5.0	5.0/25	5.0/25	4.0/20	4.0/20
LOGISTICS REQUIREMENTS	10.0	4.0/40	4.5/45	4.0/40	3.0/30
FACILITIES REQUIREMENTS	7.0	4.0/28	4.0/28	4.0/28	4.0/28
PECULIAR EQUIPMENT	7.0	2.0/14	3.0/21	3.0/21	3.0/21
VEHICLE WEIGHT CONTRIBUTION	7.0	4.0/28	2.0/14	3.0/21	2.0/14
TOTAL	107.0	367	353	378	346
FIGURE OF MERIT		3.42	3.29	3.53	3.23
RANK NUMBER		1	2	1	2

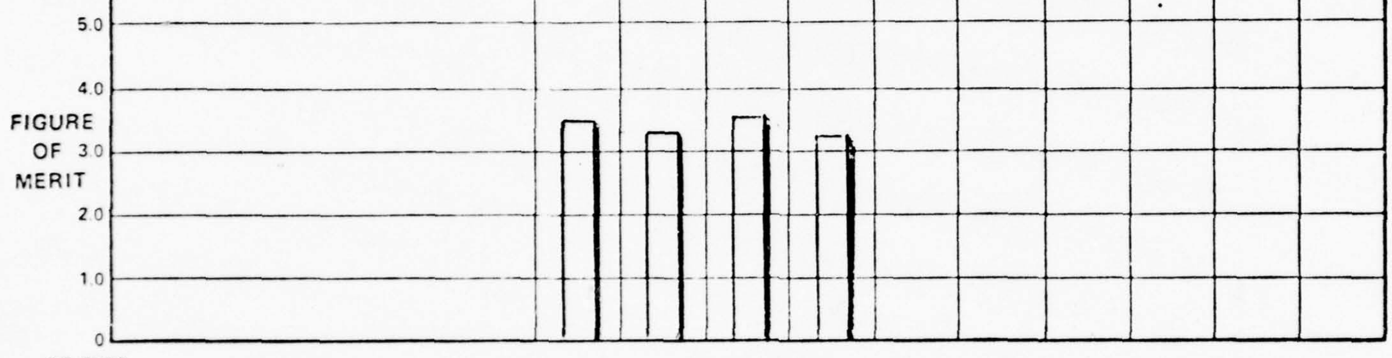

Figure 3.7-2. Assessement Sheet #6(a) - Water/Snow Assessment

3.8 ASSESSMENT SHEET NO. 7 - CONVENTIONAL LANDING - RETARDATION SYSTEMS

3.8.1 General Considerations

This group comprises three functionally similar, but technically diverse subsets of recovery elements as follows:

a. Four externally applied arresting systems (each interfacing with a wheeled vehicle without brakes)

b. Two integral decelerators, namely the parabrake and the thrust reverser, each with four types of surface/vehicle interface subsystems

c. Three integral retardation mechanisms reacting directly against the landing surface.

Each subset was assessed separately, although they all appear on the same sheet presented in Figure 3.8-1.

3.8.2 External Arresting Systems

Among the four external arresting systems - the Water Twister arrester gear was rated highest. This was followed by the landing barrier (with a capture net), the anchor chain and finally the pop-up cable, strut engaging device.

Water twister arresting system was rated high in tactical mobility, relative low cost, and predictable and well proven rapid cycle operation. Its adverse points were lack of flexibility, once the system in installed, and actual system handling under diversified environmental conditions.

Landing barrier, which can either employ a water twister decelerator or actual disk brake pads - has much slower recovery cycle when compared with the arresting gear system, because of a more complicated recovery

A_j

SCALE OF ACCEPTANCE

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

W_i

OPERATIONAL WEIGHTING FACTORS

10.0 EXTREMELY IMPORTANT
7.0 IMPORTANT
5.0 AVERAGE EFFECT
3.0 LESS THAN AVERAGE EFFECT

A_j

CRITERIA (W_i)	WEIGHT FACTOR	AIR CUSHION INTEGRAL	WHEELS AND BRAKES	MAGNETIC LANDER	NO BRAKES: WATER TWISTER ARR. GEAR	NO BRAKES: POP-UP ARREST. GEAR	NO BRAKES: ANCHOR CHAIN	NO BRAKES: LANDING BRAKES	PARABRAKE OR TH. REVS.: AIR CUSHION INTEGRAL	PARABRAKE OR TH. REVS.: WHEELS AND BRAKES	PARABRAKE OR TH. REVS.: COMBO W/S	PARABRAKE OR TH. REVS.: SKIDS
COST	10.0	4.5/45	3.5/35	3.0/30	6.0/60	4.0/40	6.0/60	4.5/45	2.5/25	3.0/30	2.0/20	3.0/30
COMPLEXITY	10.0	4.0/40	3.5/35	3.0/30	4.0/40	2.5/25	5.0/50	3.0/30	4.0/40	3.0/30	3.0/30	4.5/45
SURVIVABILITY	10.0	2.5/25	3.0/30	6.0/60	7.0/70	4.0/40	5.0/50	7.0/70	4.5/45	4.0/40	4.0/40	3.5/35
TECHNICAL RISK	5.0	4.0/20	6.0/30	1.5/7.5	6.0/36	4.0/20	4.0/20	6.0/30	4.0/20	5.0/25	3.0/15	6.0/30
FLEXIBILITY	7.0	6.0/42	4.0/28	2.0/14	2.0/14	3.0/21	2.0/14	4.0/28	5.0/35	5.0/35	4.0/28	4.0/28
LAUNCH RATE (RECOVERY RATE)	10.0	3.0/30	3.5/35	4.0/40	6.0/60	3.0/30	1.0/10	2.5/25	5.0/50	5.0/50	4.0/40	3.5/35
AVAILABILITY	5.0	4.0/20	4.0/20	5.0/20	5.0/25	3.0/15	6.0/30	4.0/20	3.0/15	3.0/15	3.0/15	4.0/20
HANDLING	7.0	2.5/17.5	4.0/28	1.5/10.5	3.0/21	3.0/21	1.0/7	2.0/14	3.0/21	5.0/35	4.0/28	3.0/21
VEHICLE COMPATIBILITY	7.0	2.5/17.5	3.0/21	2.0/14	5.0/35	3.0/21	6.0/42	7.0/49	2.5/17.5	3.0/21	3.0/21	4.0/28
SYSTEM COMPATIBILITY	5.0	3.0/15	3.0/15	2.0/10	4.0/20	3.0/15	2.0/10	3.0/15	2.5/12.5	5.0/25	3.0/15	3.0/15
LOGISTICS REQUIREMENTS	10.0	4.0/40	5.0/50	2.5/25	4.0/40	3.0/30	5.0/50	3.0/30	3.0/30	3.0/30	2.0/20	3.0/30
FACILITIES REQUIREMENTS	7.0	3.0/21	2.0/14	4.0/28	6.0/42	5.0/35	5.0/35	6.0/42	4.0/28	4.0/28	4.0/28	4.0/28
PECULIAR EQUIPMENT	7.0	3.0/21	4.0/28	2.0/14	4.0/28	3.0/21	5.0/35	4.0/28	3.0/21	4.0/28	3.0/21	3.0/21
VEHICLE WEIGHT CONTRIBUTION	7.0	4.0/28	3.0/21	3.0/21	6.0/42	6.0/42	6.0/42	7.0/49	3.0/21	3.0/21	2.0/14	3.0/21
TOTAL	107.0	382	390	324	538	376	455	475	381	413	335	387
FIGURE OF MERIT		3.57	3.64	3.02	4.98	3.51	4.25	4.43	3.56	3.85	3.13	3.61
RANK NUMBER		2	1	3	1	4	3	2	3	1	4	2

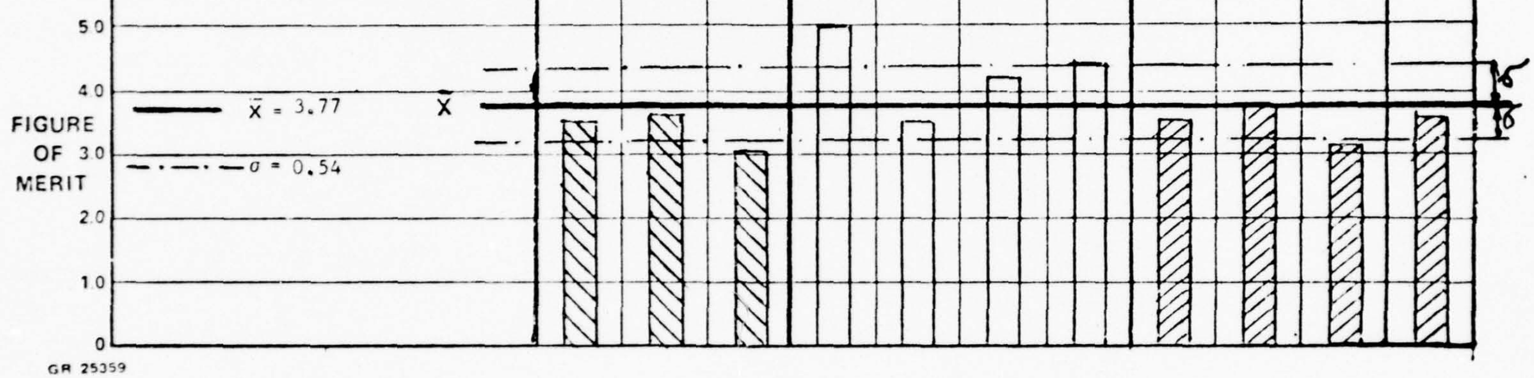

Figure 3.8-1. Assessment Sheet #7 - Conventional Landing Retardation Systems

operation. However, it demands very little from the vehicle in the way of specific requirements, and contributes nothing to vehicle mission weight (such as the arrester hook system.) The vehicle survival rate on recovery can also be considered excellent.

Anchor chain arrester is probably the simplest arresting system, absorbing the kinetic energy of the landed vehicle in the work necessary to drag the anchor chain on the ground. Its problems are the poor recovery cycle and excessively involved ground handling which is not compatible with high recovery rates demanded by the system.

"Pop-up" strut engaging devices have been designed primarily to act as the terminal decelerators for emergency stopping of large aircraft which were not capable to convert to arresting hooks systems on account of excessive stress concentration. The level of damage to the vehicle-struts, the ancillary equipment lines (such as brake lines),scissors, and the costly installation and rather poor reliability of the system (less than 50%) makes it a least attractive arrester of the four types considered.

3.8.3 The Integral Decelerators

The parabrake and the thrust reverser in their functional impact on the vehicle behavior and deceleration after touchdown are quite similar and for this reason they have been evaluated as one generic group employing four different surface/vehicle interface units. The numerical F.O.M.s represent the value for the combination, i.e., the parabrake (or thrust reverser) plus one of the four of these units.

The assessment rating of these two integral arrestors was generally low on account of cost, complexity, logistics requirements and the mission weight contribution. There was comparatively little difference between the interface system employed in conjunction with these decelerators. The conventional wheels and brakes were rated best followed by skids, integral air cushion and combo wheels/skids systems.

Wheels and Brakes - This conventional retardation method rated only average in the ARPV application. When using this system alone for the deceleration of the vehicle, a controller's command link must be maintained during the run-out and a nose wheel steering mechanism appears essential. The retardation performance on the grass fields is much lower than on prepared runways, and is also less predictable. This affects the vehicle survivability, and tends to increase the size of the landing field. Both cost per vehicle and the system complexity increase. The recovery rates are adversely affected because of the need to control and to monitor the vehicle progress in recovery until it reaches safety areas. Most of the vehicle control after touchdown could be automated, but this would add the cost and the complexity.

Integral Air Cushion - In the LA-4 and the Buffalo ACLS the braking is obtained by separately inflatable pillows built into the trunk to make contact with the ground upon inflation of the pillows. The pillows are reinforced with the abrasion resisting friction pads. The inflation of the pillows raises adjacent areas of the trunk body causing the escape

of air cushion and increased reaction on the brake pillows. The problem of maintaining adequate control of the vehicle during ground run, particularly its heading and its orientation in azimuth is critical in both the launch and the recovery phase. It determines the location of the vehicle after the runout and affects the subsequent chain of activities. The ACLS, as it is conceived at this date, was rated low in the above aspects as it has, as yet, not solved the problem or sideforce control adequately. The flexibility and better than average cost give the advantageous points, while the ground handling, the impact on the vehicle/mission design and low survivability because of the controllability problems were the detrements in this assessment.

Magnetic Lander - This recovery concept was included in the assessment because it promises a number of features which could revolutionize the RPV's recovery field in the future. The high points of this concept, for the retardation of the RPV, are the survivability and reduced facility requirements. If the control of the vehicle over the center of the magnetic flux can be achieved, then the handling of the vehicle over its conducting ground sheet could be precise enough to proceed with an all automatic control of the vehicle throughout its ground operating cycle. If the conducting ground sheet is to be only limited to the runout areas, then it will be necessary to "dolly-up" the vehicle after removal from the conducting sheet. The principle of Magnetic Lander operation is shown in the Glossary of Terms - Appendix page A-27.

3.9 ASSESSMENT SHEET NO. 8 - VERTICAL INTEGRAL RECOVERY - GROUND INTERFACE SYSTEMS

The results of assessment of vertical integral recovery systems indicated that the dual mode - parachute was a preferred system followed by the VTOL system. Both of these recovery methods were therefore assessed for their preferred ground/vehicle interface. This assessment is presented in Figure 3.9-1.

3.9.1 Dual Mode Parachute

The "dual mode" capability of this equipment lies in the airborne (MARS) as well as conventional recovery method. A successful MARS recovery does not normally result in any damage to the vehicle, as the vehicle is lowered onto the ground by the helicopter. If, however, the MARS recovery fails, or is not available, then the system reverts to a basic parachute recovery and needs impact protection from damage at terminal velocities of approximately 20-25 ft/sec. The seven categories of these interfaces have been assessed , and are briefly described below.

Low Pressure Tire

This conceptual impact attentuator was rated highest. In its stowed status the low pressure tire is completely deflated occupying a very small volume. The system is activated with deployment of the parachute, when the tire is overinflated to maximum permissible volume. On impact the excess pressure is blown off to prevent rebound. On coming to rest the vehicle can be towed or parked on this single tire, the fore and aft and lateral tilting being prevented by a set of integral skids. The practicability of this system depends on the tire design and development of suitable, controlled shape,elastic material. The high ratings in this system are

A_j

SCALE OF ACCEPTANCE

7.0	EXCELLENT	3.0	LESS THAN AVERAGE
6.0	VERY GOOD	2.0	POOR
5.0	GOOD	1.0	VERY POOR
4.0	AVERAGE	0.0	UNACCEPTABLE (INVALIDATES CONCEPT)

$$FOM_j = \frac{\sum_{i=1}^{14} W_i A_j}{\sum_{i=1}^{14} W_i}$$

W_i

OPERATIONAL WEIGHTING FACTORS

10.0 EXTREMELY IMPORTANT
7.0 IMPORTANT
5.0 AVERAGE EFFECT
3.0 LESS THAN AVERAGE EFFECT

CRITERIA (W_i)	WEIGHT FACTOR	PARACHUTE: RETRO ROCKETS	PARACHUTE: IMPACT ATTEN.	PARACHUTE: AIR BAGS ONLY	PARACHUTE: SKIDS & AIR BAGS	PARACHUTE: BODY REIN-FORCEMENT	PARACHUTE: LOW PRESS. BALLOON TIRE	PARACHUTE: PALLET & AIR BAGS	VTOL/BALLOON: WHEELS VTOL	VTOL/BALLOON: SKIDS VTOL/WHEEL	A_j
COST	10.0	2.0/20	3.0/30	5.5/55	4.5/45	3.0/30	4.0/40	3.5/35	3.0/30	3.0/30	
COMPLEXITY	10.0	3.0/30	4.5/45	4.0/40	4.0/40	6.0/60	4.0/40	3.5/35	3.0/30	3.0/30	
SURVIVABILITY	10.0	3.0/30	4.0/40	3.5/35	4.0/40	2.0/20	4.0/40	4.0/40	5.0/50	5.5/55	
TECHNICAL RISK	5.0	3.0/15	3.0/15	3.5/17.5	3.0/15	4.0/20	2.0/10	3.0/15	5.0/25	5.0/25	
FLEXIBILITY	7.0	4.0/28	2.5/17.5	3.0/21	4.0/28	2.0/14	6.0/42	3.0/21	4.0/28	4.0/28	
LAUNCH RATE (RECOVERY RATE)	10.0	2.5/25	2.5/25	2.5/25	4.0/40	2.0/20	6.0/60	2.5/25	5.0/50	3.5/35	
AVAILABILITY	5.0	3.0/15	1.5/7.5	2.5/12.5	3.0/15	2.5/12.5	3.0/15	3.0/15	4.0/20	4.0/20	
HANDLING	7.0	1.5/10.5	2.0/14.0	3.0/21	3.0/21	1.5/10.5	6.0/42	3.0/21	6.0/42	3.0/21	
VEHICLE COMPATIBILITY	7.0	2.5/17.5	3.0/21	2.5/17.5	3.0/21	4.0/28	4.0/28	2.5/17.5	4.0/28	3.0/21	
SYSTEM COMPATIBILITY	5.0	1.5/7.5	2.0/10	4.0/20	4.0/20	2.5/12.5	5.0/25	2.5/12.5	6.0/30	4.0/20	
LOGISTICS REQUIREMENTS	10.0	3.0/30	4.0/40	3.0/30	3.5/35	2.0/20	4.0/40	2.5/25	4.0/40	4.0/40	
FACILITIES REQUIREMENTS	7.0	2.5/17.5	3.0/21	3.0/21	3.0/21	3.0/21	3.0/21	2.5/17.5	6.0/42	6.0/42	
PECULIAR EQUIPMENT	7.0	4.0/28	4.0/28	3.0/21	3.0/21	5.0/35	4.0/28	3.5/24.5	5.0/35	5.0/35	
VEHICLE WEIGHT CONTRIBUTION	7.0	6.0/42	4.0/28	3.0/21	4.0/28	4.0/28	4.0/28	3.0/21	4.0/28	5.0/35	
TOTAL	107.0	316	342	357.5	390	331.5	459	325	478	437	
FIGURE OF MERIT		2.95	3.19	3.34	3.64	3.09	4.28	3.03	4.46	4.08	
RANK NUMBER		7	4	3	2	5	1	6	1	2	

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Figure 3.9-1. Assessment Sheet #8 - Vertical Integral Recovery - Ground Interface Systems.

flexibility and post recovery handling. In this group of interface elements any system which upon impact allows instant mobility without the need of cranes and tow dollies represents a considerable advantage in operational handling - at high sortie rates.

The low rating were allotted to the technical risk associated with this concept and possible problems with maintainability.

Skids and Airbags

This concept combines the shock attenuation of the airbag with the partial mobility of the skid. As illustrated in Glossary of Terms, the skids are integral with the bottom of the vehicle and they are backed by the airbag system to supplement the shock absorbtion of the basic skid absorbers. After recovery the system can be towed on the teflon skids over most of the surfaces. The technical solution to this concept is not simple as the system has to absorb between 34,000 - 40,000 ft lbs of kinetic energy within 1.0 to 1.5 feet distance by distribution of the impact reaction over a limited available contact area.

Airbags

This system has been developed and tested for the existing drones (BGM-34M series). The inflatable bag is carried externally in a conformal shape and is activated by the compressed air from a bottle carried onboard of the vehicle. In addition the system comprises supply lines, check and aspirator valves and a set of blow-off seal caps to relieve the pressure on impact and prevent a rebound. A more detailed description of the system is given in the Glossary of Terms in the Appendix. In the overall rating the system scored third. Its drawbacks are poor recovery rate (related to extraneous activities connected with attaining mobility), maintainability problems,

the system complication of many parts and functions and finally contribution to external vehicle drag.

Impact Attenuators

The primary candidate for this approach is a commercial strut development known by trade name of TOR SHOK(R). It is basically a multiple telescoping metal tubing. Placed between the tubes is a length of bound wire which deformates in reaction to the relative movement between the tubes either in compression or extension. This system once used can be reset to be reused again. Either three or four of these attenuators could be retracted into the bottom of the RPV body and lowered to the recovery position after deployment of the parachute. The used articles after recovery would be directly replaced by either new or reset items, and locked into place for the next mission.

In the overall assessment this system showed a number of potential shortcomings: (1) Poor handling, the adverse effects on maintainability and system operation and resultant low recovery rate. The presence of a lifting crane and recovery vehicle is inevitable with attendant manpower and transportation requirements.

Body Reinforcements

The shock attenuation capability of crushable materials lends itself to application in the parachute recovery mode. The concept envisages body fitting crushable sections which are readily replaceable after usage. They are extendable prior to impact and perform work together with the extensors. They score heavily in the assessment in points relating to vehicle compatibility, lack of complexity and absence of peculiar equipment to accompany the system. The detrimental aspects are the logistics and system handling after recovery. The low rating in the availability reflects the potential damage pronness if the impact force is not evenly distributed on landing.

Pallet and Airbags

The pallet airbag impact attenuator has been extensively used with success in aerial drop delivery techniques of truck, jeeps and even medium sized tanks. The problems with this type of system in RPV application is in the area of vehicle compatibility, logistics and actual handling after recovery that affects the turn around and availability of the system for the next sortie. The pallet would have to be an integral part of the vehicle body and would have to blend with it with minimum contribution to weight and drag. The current application is suitable only for stores with near vertical descents and internal carriage in the logistic-drop aircraft.

Retro-Rockets

Were rated low because of their total dependence on ground proximity sensing equipment, their presence onboard the vehicle during the mission, the weight and packaging problems and last but not least the complexity, the cost and the safety of vehicle handling while on the ground. In addition to the retro-units and the associated system - the vehicle would still have to carry some measure of impact attenuation to ensure that no, or only negligible damage to the structure resulted.

3.9.2 The VTOL Systems

It was mentioned earlier that out of the field of potential systems, the VTOL configuration that was considered in this trade study was the augmented wing concept similar to XVF 12A, now under development at Rockwell International Columbus. This group of equipment was assessed on the assumption that the vertical velocity component during the terminal contact was very low, in the neighborhood of 0 - 15 ft/sec (max.).

VTOL - Tricycle Wheel Gear

The retractable VTOL wheeled gear was rated highest because of its simplicity, ground mobility and low technical risk. The retraction concept making this system attractive from the drag point of view can be incorporated with ease. The wheeled gear has also the advantage of providing rolling STOL interface in case of VTOL overload.

Skids/Wheels (VTOL/Wheels for mobility over prepared surfaces)

This concept is described and illustrated in Glossary of Terms in the Appendix. The system is retractable for drag reduction. This adds to complexity and cost. The adverse aspects of this concept are limited mobility and general confinement to prepared level surfaces. Also in this concept, the transfer from VTOL to STOL operation is not feasible.

4.0 ELIMINATION PROCESS

4.1 FIRST ITERATION MATRIX

The objective of the POED assessment to this point was to perform a trade study selection between the candidate elements from the group of morphological matrices. As this was accomplished, it was decided that the best way to avoid missing a potential system was to perform the selection in two ways (1) to select the best three as shown by POED assessment sheets and (2) to supplement selectively those best three systems by any other system which is particularly compatible with the ARPV mission although its ranking based on Figure of MERIT might have been inferior.

This process resulted in the "FIRST ITERATION MATRIX" shown in Figure 4.1-1 which reduced the number of potential launch and recovery candidates to a manageable level. It comprised a majority of the systems included in the Statement of Work, paragraphs 3.2.3 - a, b and c, for subsequent analysis.

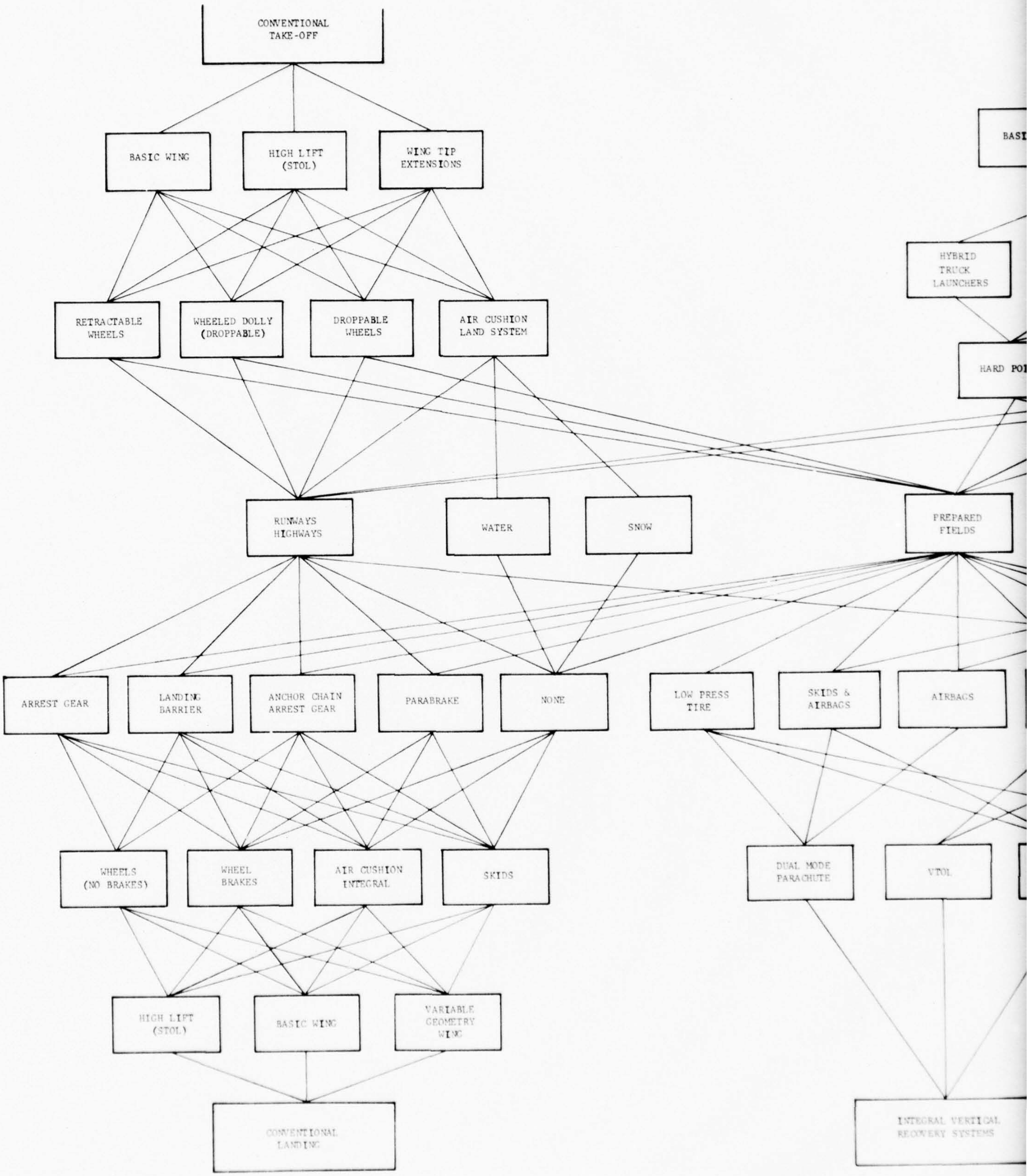
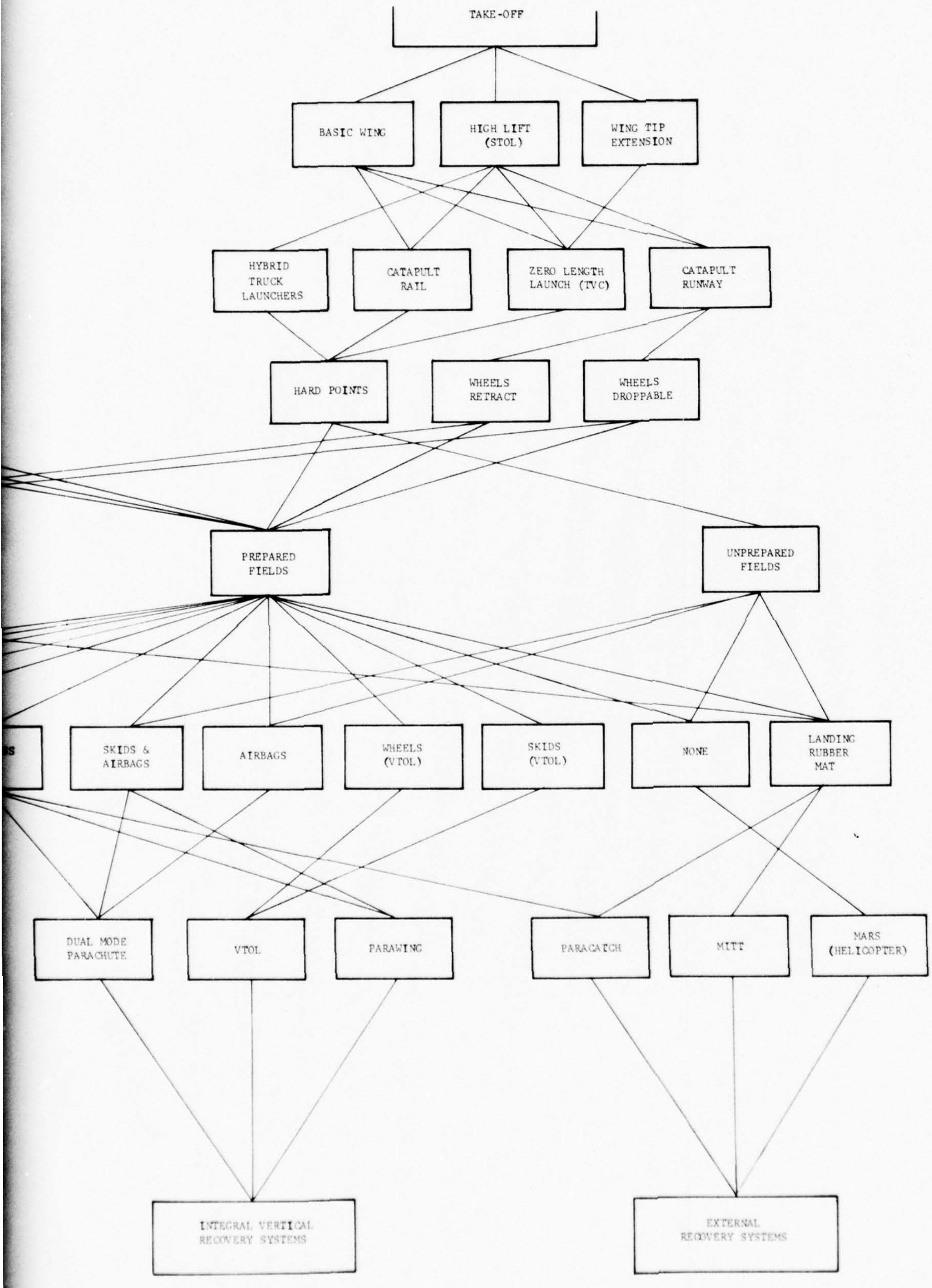


Figure 4.1-1 First Iteration Matrix



2

Iteration Matrix

The critical review of first iteration matrix indicated that in addition to numerous technically feasible and economically practical launch and recovery systems, that this matrix could generate, there were also many which were incongruous as they meant duplication and lack of intercompatibility and in some combination of elements were quite impractical.

As a result of this review a second iteration matrix was generated with the objective of further reducing the potential field of Launch and Recovery candidates. The process of assessment sheets review continued together with the elimination of less practical candidates and their combinations. In addition, the Logistic Group was asked to perform a POED assessment of their own emphasizing the logistic aspect of Launch and Recovery.

The comparison between the two POED assessments is shown in Figure 4.1-2. The original Launch and Recovery POED ratings are shown in a continuous line, while the logistic assessment is denoted by the dashed line. The results indicate that the difference between the individual system rank was on average 1.58 with a standard deviation of 0.82. It can be seen that in 17 out of 70 cases the ranking was identical, in 19 cases it differed by only one rank level. These results indicated that the logistic aspects of L&R correlate reasonably close with the original operational assessment of the systems concepts.

It should be noted that the second iteration matrix which resulted from the combined analyses and reviews of the assessment sheets and the logistic inputs has not as yet been subjected to vigorous impact of detailed mission requirements. It was still a generalized selection process to limit the number of candidate systems to a practical level for a more comprehensive cost/benefit analysis.

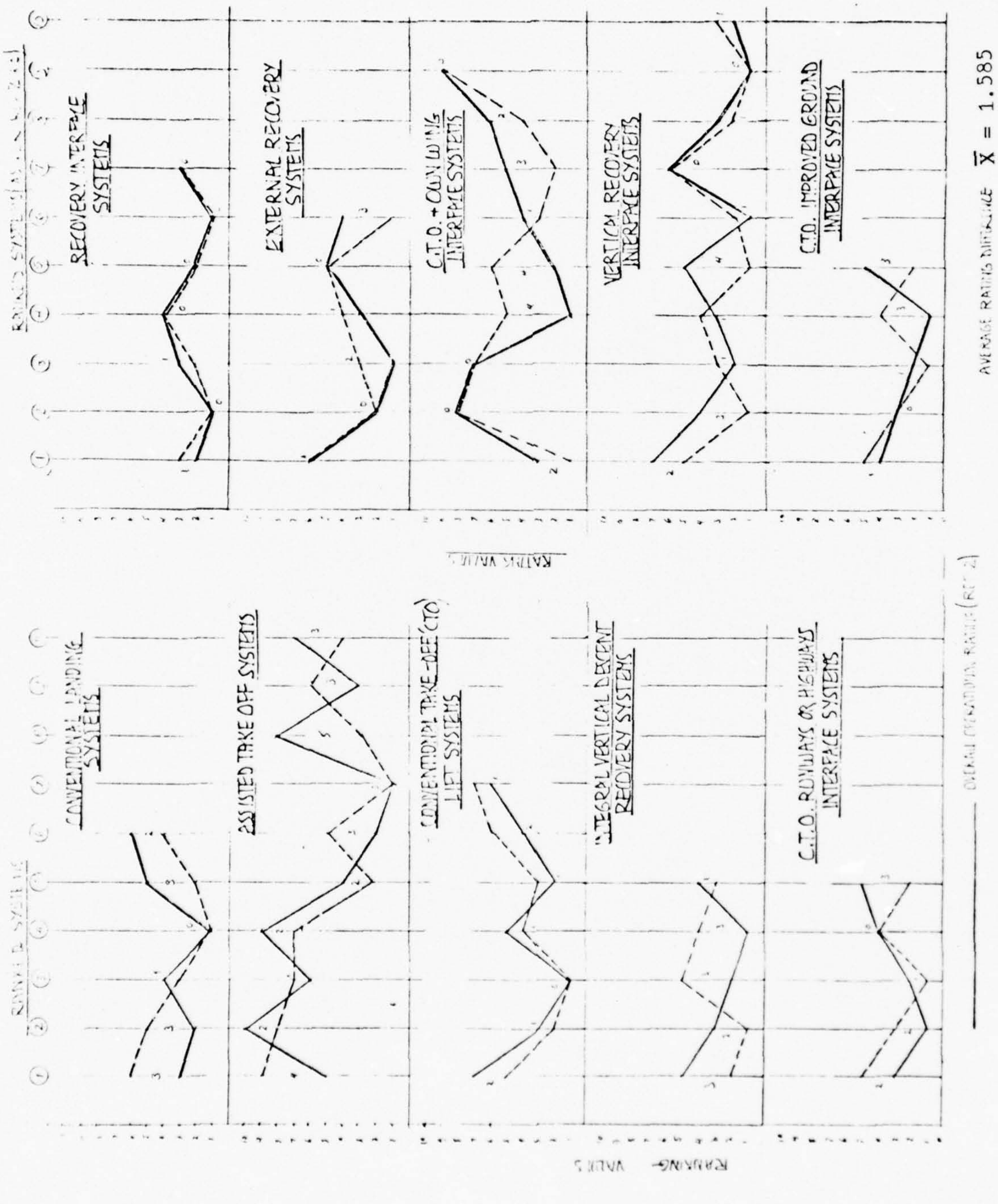


Figure 4.1-2 Ranking Correlation Between Operational and Logistic Approach to Assessment

4.2 SECOND ITERATION MATRIX

The second iteration matrix is shown in Figure 4.2-1.

Listed below are the elements of the first iteration matrix that have been droppedfrom inclusion in the second interation matrix together with the principal reasons for their removal from further analysis.

Unprepared Fields	The ARPV operations will be conducted from three bases prepared in advance. The operation from unprepared fields will be unlikely even in the event of abandoning these bases. The time necessary in establishing a tactically responsive operation from unprepared fields on "ad hoc" basis with the attendant complication of logistics support and theater inter-communications is not compatible with large sortie operation. The "fall back" bases adequately prepared may be required.
Vertical Landing Systems	The powered vertical landing system is intrinsically linked with the vertical take-off - the system which was considered poor in acceptance from the cost and complexity and rejected for first iteration matrix. The augmentation factor required to lift approximately 7000 lbs load vertically with the existing RPV engines would be about 2.5 and this has not been achieved as yet in augmentor wing development.

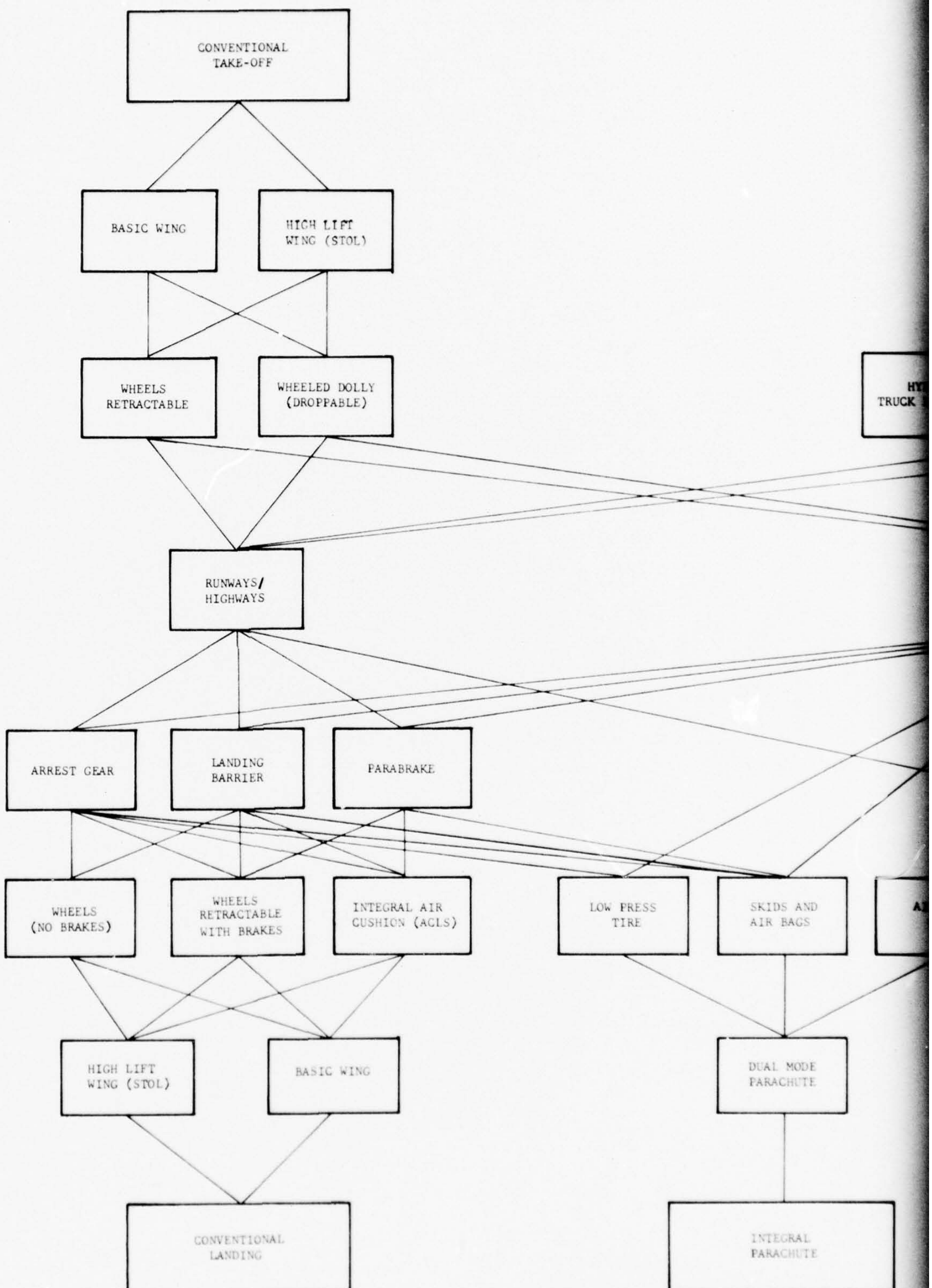
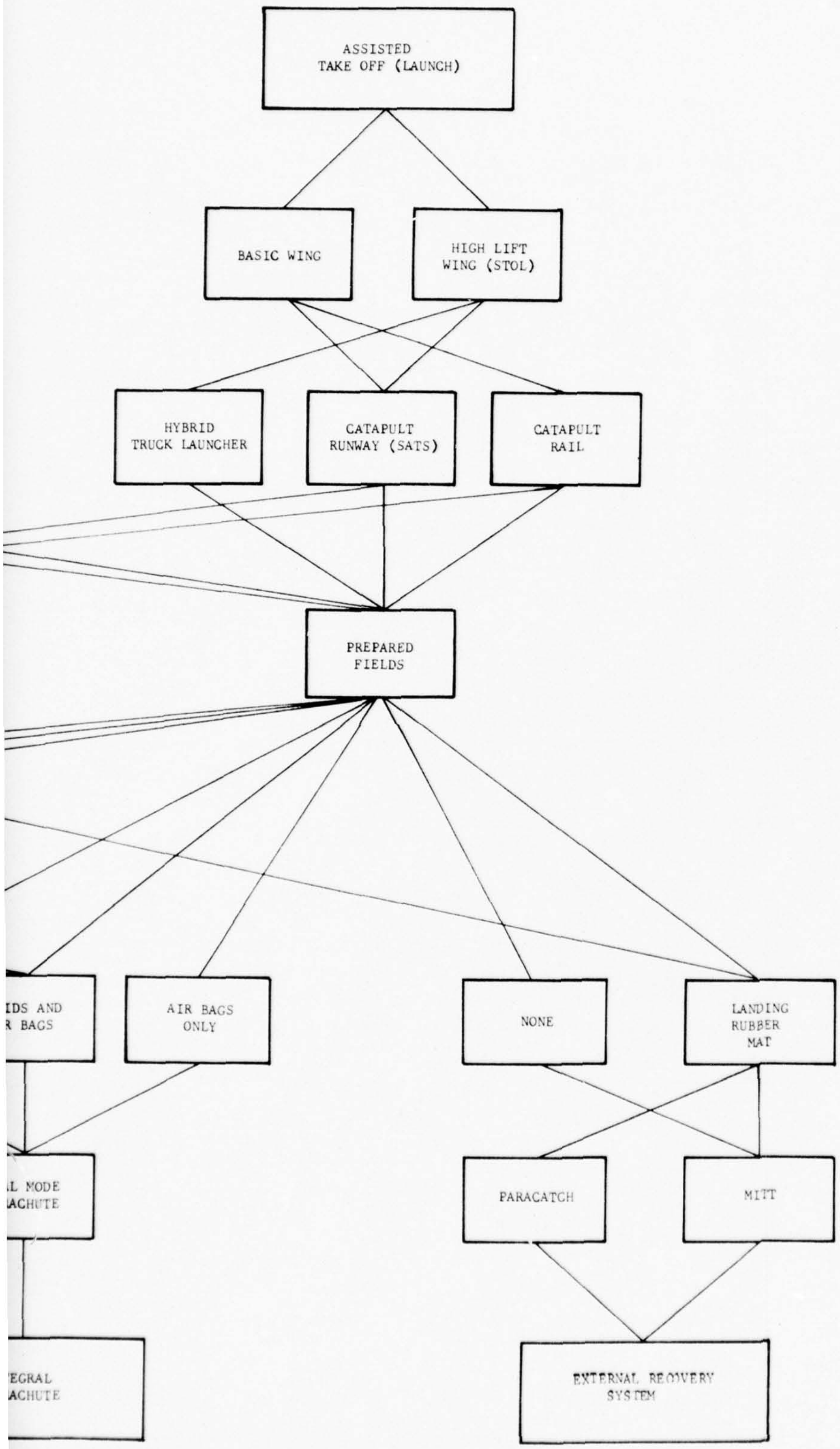


Figure 4.2-1 Second Iteration

2



d Iteration Matrix

Parawing	Lack of control precision, large bulk and turn around complications.
MARS	Launch rate and recovery rate not compatible with massive sortie operation.
Variable Geometry Wing	Excessive complication, weight, and high cost to achieve something that can be obtained more simply (STOL/high speed airfoil.)
Droppable Wing Tips (On Take-Off)	Excessive logistics - no relief for the landing case.
Droppable Air Cushion Dolly	Not considered suitable for high sortie rate system. Poor ground handling and subject to strong environmental effects (wind, freezing up).
Zero Length Launcher (TVC)	Not suitable for high sortie rate and rapid turn-around time. It represents a "one wave" capability with long delay between launch "waves". A very high cost sortie system.
Droppable Wheels	To retain wheels in the vehicle after take-off is a small price to pay for logistics and maintenance problems connected with this system.
Anchor Chain-retard System	Poor recovery rate and excessive manpower requirements.

In all, the second iteration matrix comprised 23 basic elements from which the final list of matched launch and recovery systems was to be formed. This matrix was the basis for a determination of a final matching list comprising complete and operationally practical launch and recovery systems. The total number of such systems as a result of element matching was approximately seventy (70).

Matching Criteria

A list of criteria which governed the system matching process is outlined below.

- Vehicle Configuration Compatibility

  Systems must be compatible as to airframe, location, volume, weight and required performance.

  Avoid unproven configurations.

  Avoid matchings resulting in dubious concepts for the sake of novelty.

- L&R Commonality

  Aim at one system for both launch and recovery

  If possible utilize elements of the same system in both launch and recovery

- Rejection of Mutually Exclusive Systems

  Consider only those systems that are mutually compatible.

- Aim at High Survivability for Both L&R
- Look for Compatible Space Requirements
- Match Systems that have Low Skills & Man Power Requirements for both L&R
- High Turn Around Time for both L&R
- Low Acquisition Cost for both L&R
- Low Technical Risk for both L&R
- High Availability for both L&R
- Low Logistics Support Requirements for both L&R
- Consider Air Launch to be a Special Case or Exclusive Capability in some Specific Cases (Recce Only)

  Not to be Considered as Automatic Back-up System to Ground Launch.

4.3 IMPACT OF MISSION REQUIREMENTS ON L&R

Following the matching process each system was analyzed for compliance with the launch and recovery requirements. These were provisionally formulated for presentation during the System Requirements Review at ARPV SPO in WPAFB on June 9, 1975, and were later reviewed and modified. (For list of requirements pertaining to L&R, see Appendix, Pages A-27 to A-37.) Among the number of requirements (or goals at that time) presented, there are four major ones which have a strong impact on L&R system selection, as follows:

(1) The dispersion distance from predicted point of impact (or stop) after recovery.

(2) The size and surface characteristics of the operating field.

(3) The capability to provide a high sortie rates in operational environment.

(4) System operating safety.

4.3.1 Dispersion Distance

To illustrate the importance of this requirement a simple example is given of a parachute descending through 2,000 feet vertically at 20 ft/sec with the original position error of 150 feet - 1 sigma (1σ) being subject to a wind velocity change in a fixed direction of 5 km (1σ). Taking the RSS of these two values the dispersion radius from the originally predicted point of impact will be 858 feet (1σ). Assuming that for safety considerations the recovery equipment must be positioned at 3σ value from the intended point of impact - then the periphery for this location becomes a circle of 2,574 feet radius, which is indeed a large area

required for this type of operation.

Initially the figure for the dispersion goal was set at 50 ft (1σ) in order to exercise the systems evolved from second iteration matrix against that goal. Only three major systems failed to satisfy this requirement - namely - the parachute recovery, the conventional landing using integral air cushion with a parabrake, and the conventional landing with a landing gear without brakes using a parabrake for deceleration.

The conventional landing method using arrester gear, landing barrier or wheel brakes (with nose wheel steering) as well as the external recovery systems (Paracath and MITT) satisfied this stringent requirement.

Later in the study, as the maintenance support functions were further investigated and the time line analyses performed for the turn-around time between the missions, the 50 ft (1σ) dispersion distance good was relaxed as it became obvious that larger dispersions were tolerable. The systems, however, which showed tendencies to larger dispersions than 200 ft (1σ) were considered the borderline because they tended to affect the size of the operating field adversely.

4.3.2 Field Size and Surface

The parametric presentation of take off distances over 50 ft. obstacle for conventional take off method is shown in Figure 4.3.2-1. The $\frac{W}{SC_{L_{TO}}}$ parameter practical range varies between 25 (for STOL configuration) and 80 - for unaugmented lift wings. The $\frac{T}{W}$ parameter for typical RPV take-off all up weights and projected engines, ranges between 0.35 and 0.70. Between these two sets of parameters the actual take-off distance can vary between 2,000 and 5,000 ft. An addition of 1,000 ft. would be required for mobility efficiency - bringing the field size between 3,000 and 6,000 feet. These dimensions are typical of a secondary category airfield which normally operates private light or sports aircraft above 5,000 lbs. all-up weight category, with or without runways and with surface hardness capable of giving multiple wheel passing (coverages) as defined by Reference (*) .

Reference (**) lists at least 56 of such airfields in the West German Federal Republic in addition to other major civil or military airfields. The cumulative number of these type of airfields in the neighboring NATO countries (including France) is 425. Their average take-off run length is approximately 3,500 feet. If we assume that the acquisition of the real estate for the ARPV bases is to be a problem in West Germany - then the secondary airfield becomes a primary candidate for this activity. In any case the track of land necessary for operational base to include the safety areas may be well in excess of 400 acres. These safety areas are normally present in the existing airfields.

* AFFDL -TR-68-88 - Analytical Landing Gear - Soil Interaction

** Interavia ABC 1973 - International Aerospace Directory Cat. 81

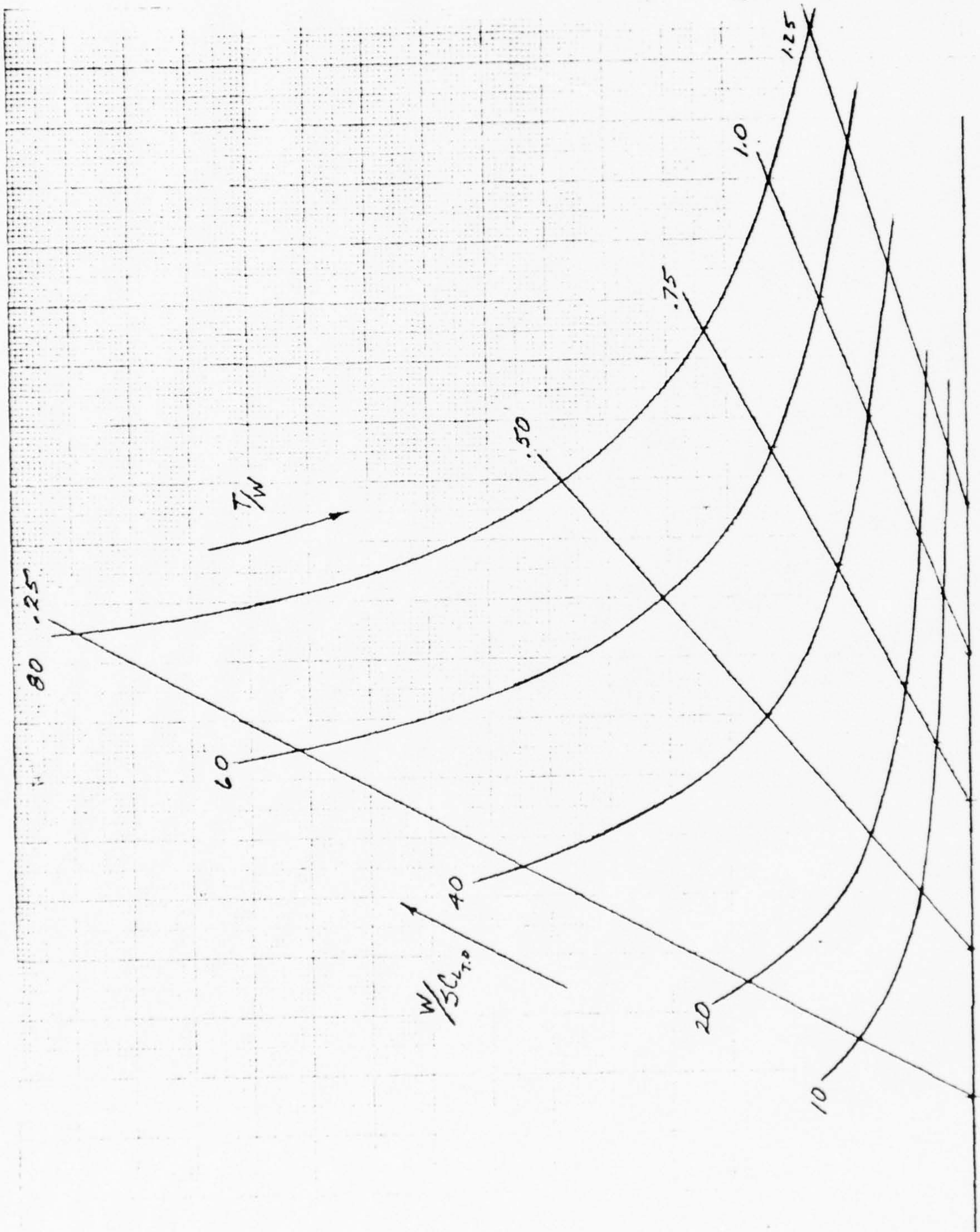


Figure 4.3.2-1. Take-Off Distance Over 50FT. (Parametric Study)

When the field requirement was exercised against the second system iteration matrix, the basic wing systems (those without lift augmentation) had to be dropped from considerations because of excessive take-off distances except in conjunction with the launch assist systems.

4.3.3 High Sortie Rates

The analysis of the mission requirements in terms of daily sortie rates indicated the need for selection of the system capable of providing up to 300 sorties per base per day. This requirement puts an emphasis on the systems with instant mobility, minimum prelaunch or post recovery activity connected with the turn-around phase of the mission and the obvious need for predictability of the operation. In applying this requirement against the second iteration matrix, the systems showing lack of predictability and in need of RPV transfer onto transporter or transport dollies before delivery to the maintenance turn-around areas took second precedence over those which could be handled directly by taxiing or towing.

4.3.4 Safety

In the absence of the pilot in command on board the vehicle all the safety aspects in operation of the ARPV must be controlled externally and also remotely. This implies for example that if the vehicle can be launched successfully by its own power without the problems associated with the assist systems, their interfaces and kinetic energy generation and disposition, then the safety aspects of the self-sustained system should be better. Any system which after becoming airborne disposes of its parts and drops them to the ground, infringes on safety aspects against the operators as well as those of the civil population

that may be in the area. In any case - the provision of safety areas is then required which adds to the requirements for the size of the operating field. In this category is also a system that barely makes "over the fence."

4.4 THIRD ITERATION MATRIX

Having applied these four "core" requirements as well as cost and complexity considerations against the second iteration matrix - several candidate systems which plainly did not satisfy the majority of them were marked as those to be removed from further consideration. These are marked with an asterisk in the list below.

	Reason	Fails Requirement
*Basic Wing	Excessive takeoff distance	Airfield Size
Wheeled Dolly Droppable	Jettison of wheeled dolly after launch	Operating Safety
*Parabrake	Unpredictability of position on recovery	Dispersion Safety
Integral Air Cushion	Unpredictability of position on recovery	Dispersion Safety High Sortie Rates
Parachute	Unpredictability on air recovery	Dispersion Safety High Sortie Rates
*Wheel Brakes with nose Wheel Steering	Complex and costly - possibly unpredictable	Dispersion Cost/Complexity
Landing Barrier	Recovery too slow for turn-around	High Sortie Rates

The third iteration matrix which was thus formulated represents a near final alignment of potential systems which were to be matched and then traded off on the cost benefits basis. This matrix is shown in Figure 4.4-1 .

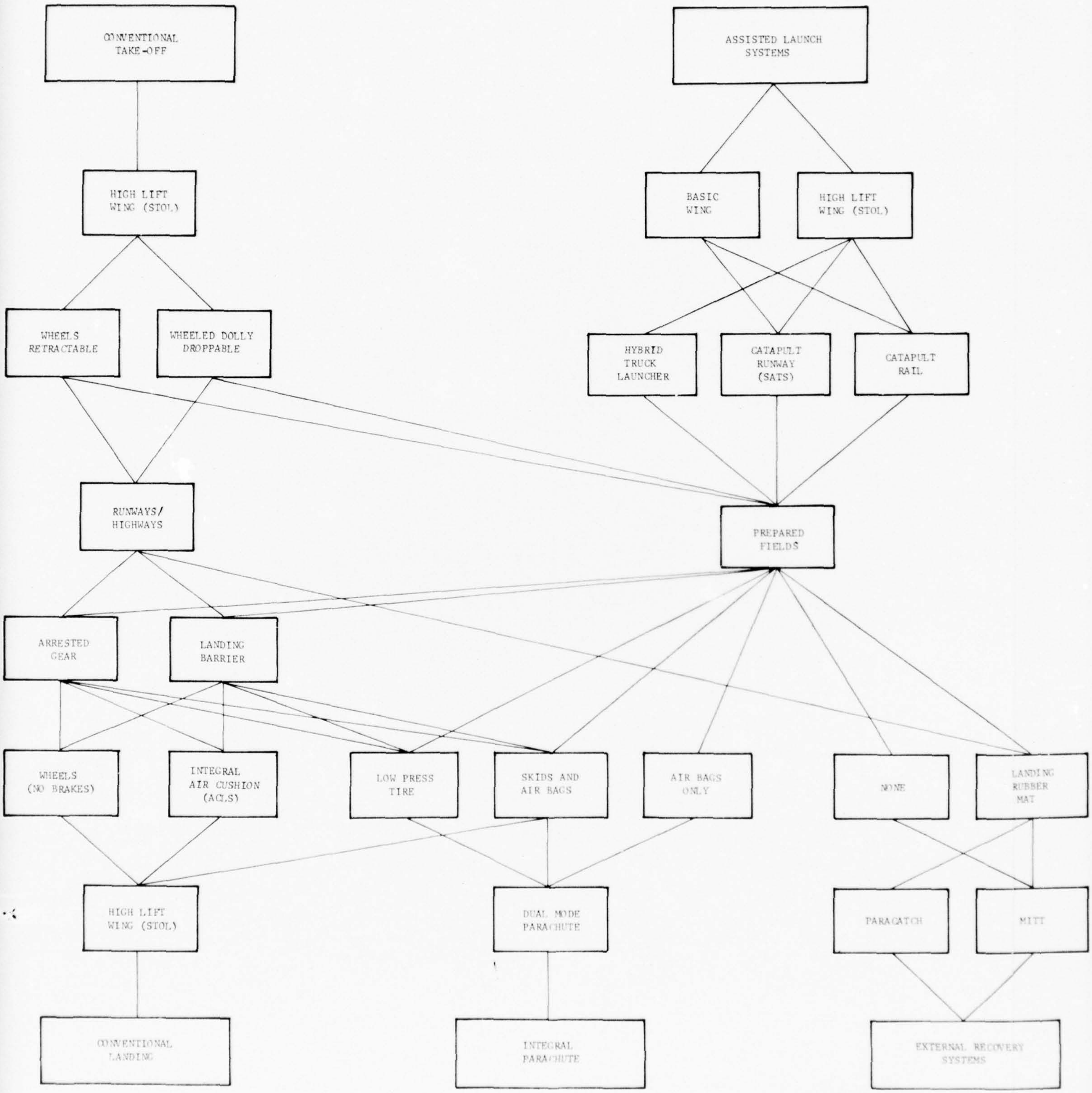


Figure 4.4-1 Third Iteration Matrix

4.5 FINAL SYSTEM MATCHING

The final list of matched systems is presented in Table 4.5-1 . It will be noted that the first four systems in that list do not derive directly from the third iteration matrix but are additional to it as follows:

(a) DC-130E/MARS

(b) ACLS MODIFIED JINDIVIK (with STOL and arrester gear)

(c) BASIC JINDIVIK TYPE (including STOL and arrest landing)

(d) Combination of b and c.

These four operational or developmental systems were included for functional trade-offs and to provide the cost base comparison for the other systems. In this list a STOL designation denotes a high lift-wing (LE and T.E. flaps) without internal or external blowing.

The matched systems of Table 4.5-1 all comprise separate launch and recovery elements which for the purpose of cost assessment can be addressed individually and in aggragation produce the input to the life cycle cost of the system.

Table 4.5-1 Final List of Matched Systems

NUMBER	VEHICLE WING/LIFT CONFIGURATION	LAUNCH SURFACE INTERFACE	LAUNCH METHOD	RECOVERY SURFACE INTERFACE	VEHICLE WING/LIFT CONFIGURATION	RECOVERY METHOD
1	Basic Wing	A/C Pylon/ Hardpoint	Air Launch DC-130E A/C	HH55 MARS Capture Kit	Dual Mode Parachute	MARS
2	STOL	Air Cushion Dolly (Droppable)	C.T.O. (conventional take off)	Air Cushion Integral	STOL	Conventional Landing Arrestor Gear
3	STOL	Wire Guided Wheel Dolly	C.T.O.	SKIDS	STOL	Conventional Landing + Arrester Gear
4	STOL	Wire Guided Wheel Dolly	C.T.O.	Air Cushion Integral	STOL	Conventional Landing + Arrester Gear
5	STOL	Wheeled Dolly (Droppable)	C.T.O.	SKIDS	STOL	Conventional Landing + Arrester Gear
6	STOL	Wheel Dolly (Droppable)	C.T.O.	Internal Air Cushion (ALLS)	STOL	Conventional Landing Arrestor Gear
7	STOL	Wheeled Dolly (Droppable)	C.T.O.	Air Bag	Dual Mode Parachute	Vertical Recovery
8	STOL	Conventional Gear	C.T.O.	Conventional Gear	STOL	Conventional Landing Arrester Gear
9	STOL	Wheeled Dolly	C.T.O.	Low Pressure Tire	STOL	Conventional Landing Arrester Gear
10	STOL	Conventional Gear	C.T.O.	External Air Mat	STOL	M.I.T.T.
11	Basic Wing	Catapult Rail	Assembly Takeoff Catapult	Air Wsh. Landing System	Basic Wind	Conventional Landing Arrester Gear
12	STOL	Wheel Dolly	C.T.O.	External Air Mat	Parachute	Paracatch
13	STOL	Conventional Gear	C.T.O.	External Air Mat	Parachute	Paracatch
14	Basic Wing	Catapult Rail	Assist Takeoff Catapult	SKIDS	Basic Wing	Conventional Landing Arrester Gear
15	Basic Wing	Catapult Rail	Assist Takeoff Catapult	External Air Mat	Basic Wing	M.I.T.T.
16	Basic Wing	Catapult Runway Conventional Gear	Assist Takeoff Catapult	Conventional Gear	Basic Wing	Conventional Landing Arrester Gear
17	Basic Wing	Rocket Shuttle	Hybrid Truck Launcher	SKIDS	Basic Wing	Conventional Landing Arrester Gear
18	Basic Wing	Rocket Shuttle	Hybrid Truck Launcher	External Air Mat	Parachute	Paracatch
19	Basic Wing	Launcher Hard Points	ZEL (TVC)	SKIDS	Basic Wing	Conventional Landing
20	Basic Wing	Rocket Shuttle	Asst Takeoff	External Air Mat	Parachute	Paracatch
21	STOL	Rocket Shuttle	Hybrid Truck Launcher	SKIDS	STOL	Conventional Landing + Arrester Gear

5.0 LIFE CYCLE COST ANALYSIS OF LAUNCH AND RECOVERY SYSTEMS

5.1 METHODOLOGY

The objective of the preceding analyses was to establish a logical and methodical elimination process in the launch and recovery selection based on the conversion of qualitative into quantitive terms and to reduce the launch and recovery candidate field to those potentially applicable in ARPV systems.

The next step in the analysis was to compare the remaining selected and matched systems in terms of cost, so that later in the study the Preliminary Design and Trade-offs Analysis (paragraph 3.1-2 of SOW), where costs and benefits are compared ,could commence leading to detailed system design. The criterion selected as a basis of cost comparison between matched systems of Table 4.5-1 is the cost per sortie. It is derived by obtaining a cumulative life cycle cost estimate of each system block element comprising the launch and recovery system in the Table and dividing it by the estimated number of RPV sorties.

In compiling the "cost per sortie" comparison between the L&R building blocks it was assumed that an RPV unit comprised 50 RPV's, the total force level was 450 RPV's and number of sorties per RPV on the average was ten, giving in all, 4,500 sorties against which the unit cost was amortizated.

The life cycle cost over a given number of years (n) has been defined by Reference * as:

$$C_{Lc(n)} = (\text{RDT\&E Cost}) + (\text{Procurement Cost}) + (\text{Total Ownership Cost}) + (\text{Disposal/Salvage Cost})$$

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* Proceedings NARPV 75 - Second Annual Symposium Life Cycle Cost Analysis As Applied To RPV RDT&E.

In the life cycle cost analysis of the launch and recovery systems only the first three terms are considered and the treatment of these terms is simplified by combining the RDT&E costs with the procurement costs and by assuming that the ownership cost over the life cycle is basically equal to both of them (except for the replacement factor described below). The ownership cost is in turn divided equally into logistic support cost and the operations cost. The logistic support segment which includes all expenditures relating to maintenance, spares inventory handling and training is modified by a "replacement factor" which implies the level of expected utilization and wear during the life cycle of a particular launch and recovery element. The operations cost includes cost of personnel, system transportation, set-up and dismantling of launch and recovery sites and expected administrative and support services, etc., needed during these operations.

A number of cost items, in both the logistic support and operations, is addressed separately in the analysis in order to allow for their actual identification and their impact on inclusion or otherwise within the given system building block. These items are as follows:

Auxiliary Equipment Costs

Cost of Facilities

Single Launch/or Recovery Cost - Materials, Personnel

Additional Logistic Cost (primarily cost of airborne transport of special equipment or stores)

Cost of Vehicle Internal Avionics Related Strictly to L&R

Cost of External Avionics Related to Launch and Recovery

5.2 LIFE CYCLE COST MATRIX

Table 5.2-1 represents a cost matrix for the Launch and Recovery building blocks identified in Table 4.5-1from which the costing of a matched or complete system is derived. The method of arriving at dollars per sortie figure in Column 17 of the matrix is shown below:

Columns

$$4 = 2 \times 3$$
$$8 = (1 + 4 + 5)7$$
$$12 = 11 \times 4500$$
$$16 = 8 + 9 + 10 + 12 + 13 + 14 + 15$$
$$17 = \frac{16}{4500}$$

Using the cost data for each of the building blocks, a life cycle cost was derived by proceeding with the arithmetics of the columns. A typical methodology of this approach is shown in Table 5.2-2 in connection with the system concept No. 8 of Table 4.5-1 which was finally selected as a base-line system. Each matched system was so costed. The results the Life Cycle Cost Per Sortie - were collected and assembled into a comparative histogram of all 21 systems under assessment shown in Figure 5.2-1 presenting from top to bottom the numerical estimates for LCC/sortie for each system.

The lowest cost system so derived was the high lift wing (STO) configuration using tricycle conventional gear in a conventional take off mode (CTO),and low speed (high lift wing) conventional landing, using arrester gear.

Table 5.2-1 Cost Matrix of Launch & Recovery Systems Building Blocks

	(1) Acquis. Cost Incl. RDT&E per Unit	(2) Replace. Factor	(3) Basic Log. Support	(4) Tot. Spt. Cost	(5) Oper. Cost	(6) No. Per Squad.	(7) No. Per Force (450 RV)	(8) Basic Life Cycle Cost	(9) Aux. Equip. Cost per Force	(10) Facilities Cost per Force	(11) Single L or R Cost	(12) Cost Per 4500 Sorties	(13) Addi-tional Log. Cost	(14) Vehicle Internal Avionics Cost	(15) External Avionics Cost	(16) Grand Total L.Cyc. Cost	(17) Cost Per Sortie (4500 S)
• Standard 3-Wheel (3 Cycle) Gear	8.0K	2.0	4.0K	8.0K	4.0K	50	450	9M	Tow. Truck 20Kx10x 9 = 1.8M	Exist. Runways 0 Highways 5M	0.5K 0.5K	2.25M 2.25M	-	15K x 450 = 6.75M	18 x 250K = 4.5M	29.3M	6511
Wheel Steerable Dolly	10K	2.0	5K	10K	5K	10	90	2.25M	Lift Tr. 20Kx10x 9 = 1.8M Tow Tr. 20Kx10x 9 = 1.8M Stat.Stand 3Kx450 = 1.35M	Highways 5M Prep. Fields 5M	0.5K	2.25M	Dolly Trans. Req. 2.0M	15K x 450 = 6.75M	18 x 250K = 4.5M	27.7M	6156
• Airborne Launch (C-130E Dedicated Vehicle)	Veh. Con. Shackle 2K •	2.0	1K	2K	1K	50	450	2.25M	Ded. C-130 5Mx12 = 60M Lift Tr. 1.8M Tow Tr. 1.8M Stat. Stnd. 1.35M	Exist. Rnwys.	3K	3.5M	15M	Nil	A/C 1.0M x 12 12M	97.7M	21,711
STOL Configuration	Wing Mods 8K	1.2	4K	4.8K	4K	50	450	7.56M	Goes with Std Gear or Whld Dolly	Goes with Std Gear or Whld Dolly		-	Incr. Weight 0.5M	Goes With Standard Gear or Dolly		8.06M	1791
• Integral Landing Air Cushion	• 4K	3.0	2K	6K	2K	50	450	5.4M	Goes With Standard Gear or Dolly		0.5K	2.25M	1.0M	Goes With Standard Gear/Dolly		8.65M	1922
Runway Catapult	• 1200K	1.1	600K	660K	600K	2	18	18x2460K = 44.28M	-	-	0.5K	2.25M	4M	-	-	50.53M	11,228
Rail Catapult (RATO)	500K	1.5	250K	375K	250K	2	18	20.25M	Goes with Dolly	-	5K	22.5M	4M	-	-	51.75M	11,500
Zero Length Launch (TVC)	Std 6K Mtr 6K Nzl 3K (TVC) 15K	1.2 1.0 1.5	3.0K 3.0K 1.5K	3.6K 3.0K 2.25K	3.0K 3.0K 1.5K	20 500 500	180 4500 4500	2.268M 54M 30.375M 86.643M	1.8M 1.8M 1.35M 4.95M	-	Incl. in Columns 1-7	-	4M	Incl. in Column 1	-	95.593M	21,243
Hybrid Truck Launcher (HTL) (Full Scale)	2 units 1000K	1.2	500K	600K	500K	2	18	2.1M x 18 = 37.8M	1.8M 1.8M 1.35M 4.95M	-	5K	22.5M	4M	-	-	69.25M	15,389
Hybrid Truck Launcher (HTL) (For STOL Only)	2 units 750K	1.1	375K	412.5K	375K	2	18	1.537M x 18 = 27.675M	4.95M	-	4K	18M	3.5M	-	-	54.125M	12,806
• Parachute	• 6K	2.0	3.0K	6.0K	3.0K	50	450	6.75M	Included with T.O.		Rec. Cost 1K	4.5M	2.0M	450x3K 1.35M	-	14.6M	3244
• Arrester Gear	• 250K	1.1	125K	137.5K	125K	4	36	512.2Kx 36 = 18.45M	Included with T.O.		0.5K	2.25M	2.0M	Included with T.O.		22.7M	5044
• MARS (Mid-Air Retr. Sys) (HH-53 Dedicated)	Para. 6K Latches + 2nd Para. 4K	2.0	5K	10K	5K	50	450	25Kx450 = 11.25M	Dedicated HH-53 12x3.46M 41.52M	-	2K	9.0M	1.0M	-	-	62.77M	13,949
Paracatch with Balloons	300K	2.0	150K	300K	150K	2	18	750Kx18 = 13.5M	4.95M	-	1K	4.5M	5.0M	-	-	27.95M	6211
MITT with								1250Kx18									

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	15K							86.64M	4.95M								
Hybrid Truck Launcher (HTL) (Full Scale)	2 units 1000K	1.2	500K	600K	500K	2	18	2.1M x 18 = 37.8M	1.8M 1.8M 1.35M 4.95M	-	5K	22.5M	4M	-	-	69.25M	15,389
Hybrid Truck Launcher (HTL) (For STOL Only)	2 units 750K	1.1	375K	412.5K	375K	2	18	1.537M x 18 = 27.675M	4.95M	-	4K	18M	3.5M	-	-	54.125M	12,806
• Parachute	6K	2.0	3.0K	6.0K	3.0K	50	450	6.75M	Included with T.O.		Rec. Cost 1K	4.5M	2.0M	450x3K 1.35M	-	14.6M	3244
• Arrester Gear	250K	1.1	125K	137.5K	125K	4	36	512.2Kx 36 = 18.45M	Included with T.O.		0.5K	2.25M	2.0M	Included with T.O.		22.7M	5044
• MARS (Mid-Air Retr. Sys) (HH-53 Dedicated)	Para. 6K Latches + 2nd Para. 4K	2.0	5K	10K	5K	50	450	25Kx450 = 11.25M	Dedicated HH-53 12x3.46M 41.52M	-	2K	9.0M	1.0M	-	-	62.77M	13,949
Paracatch with Balloons	300K	2.0	150K	300K	150K	2	18	750Kx18 = 13.5M	4.95M	-	1K	4.5M	5.0M	-	-	27.95M	6211
MITT with Balloons	500K	2.0	250K	500K	250K	2	18	1250Kx18 = 22.5M	4.95M	-	1.5K	6.75M	6.0M	-	-	40.2M	8933
Skids (incl. tow wheels)	8K	2.0	4K	8K	4K	50	450	20Kx450 = 9.0M	Incl with T.O.	-	0.5K	2.25M	-	Included with T.O.		11.25M	2500
• Airbags (Int) for Attenuators Para. Paracatch & MITT	3K	4.0	1.5K	6.0K	1.5K	50	450	10Kx450 = 4.725M	4.95M	-	0.5K	2.25M	1.0M	Included		12.925M	2872
Low Pressure Tire (Inflight Inflated)	6K	3.0	3K	9K	3K	50	450	18Kx450 = 8.1M	1.8M	-	0.5K	2.25M	1.0M	-	-	13.15M	3144
• Airbags (Ext) Attenuators (MITT & Paracatch only)	5K	3.0	2.5K	7.5K	2.5K	30	270	4.05M	-	-	-	-	1.0M	-	-	5.05M	1122
External Air Cushion/Dolly T.O. Only	8K	3.0	4K	12K	4K	10	90x15K Dolly Air Pwr 90 1.35M	2.16M	1.8M 1.8M 1.35M	0	0.5K	2.25M	2.0M	6.75M Jet Defl. on A/C 2.7M	4.5M	26.66M	5924
External Air Cushion/Dolly on Stretch Wire	8K	2.5	4K	10K	4K	10	90 1.35M	1.98M X	4.95M 4.95M X	Int.	0.2K	0.9M	Matt. & Anchors 4.0M X	Matt. Cost 18x100K = 1.8M X	Ext. Guide Wire Sys 18x150K x2=5.4M	20.38M	4528
Wheeled Dolly on Stretch Wire	10K	1.5	5K	7.5K	5K	10	90	2.025M	4.95M		0.2K	0.9M	4.0M	1.8M	5.4M	19.07M	4237
Runway Catapult (STOL)	900 K	1.1	450K	495K	450K	2	18	33.21 M	-	-	0.5K	2.25M	3.0M			38.45M	8544

Columns

4 = 2x3

8 = (1 + 4 + 5)7

12 = 11 x 4500

16 = 8 + 9 + 10 + 12 + 13 + 14 + 15

17 = $\frac{16}{4500}$

Table 5.2-2 Life Cycle Cost of Matched Systems (Methodology)

LIFE CYCLE COST OF MATCHED SYSTEMS (METHODOLOGY)

	MATCHED SYSTEM CONCEPT #1	CONV. GEAR	STOL	ARR GEAR	MLS
		1	2	3	4
BASIC SUBSYSTEM COST	PROCUREMENT INCLUDING RDT&E	3.6$\overline{M}$	3.6$\overline{M}$	9.0$\overline{M}$	11.25$\overline{M}$
	LOGISTIC SUPPORT	3.6$\overline{M}$	2.16$\overline{M}$	4.95$\overline{M}$	INCL
	OPERATIONS	1.8$\overline{M}$	1.8$\overline{M}$	6.75$\overline{M}$	INCL
	BASE SUPPORT	9.5$\overline{M}$	NIL	2.0$\overline{M}$	INCL
	TOTAL	18.55$\overline{M}$	7.56$\overline{M}$	22.7$\overline{M}$	11.25$\overline{M}$
	GRAND TOTAL LIFE CYCLE COST = L_{CCT}	60.060$\overline{M}$			
	TOTAL NUMBER OF SORTIES PER SYSTEM	(450 x 10 = 4500)	4500		
	COST PER SORTIE	$L_{CCT}/4500$ = \$13,346			

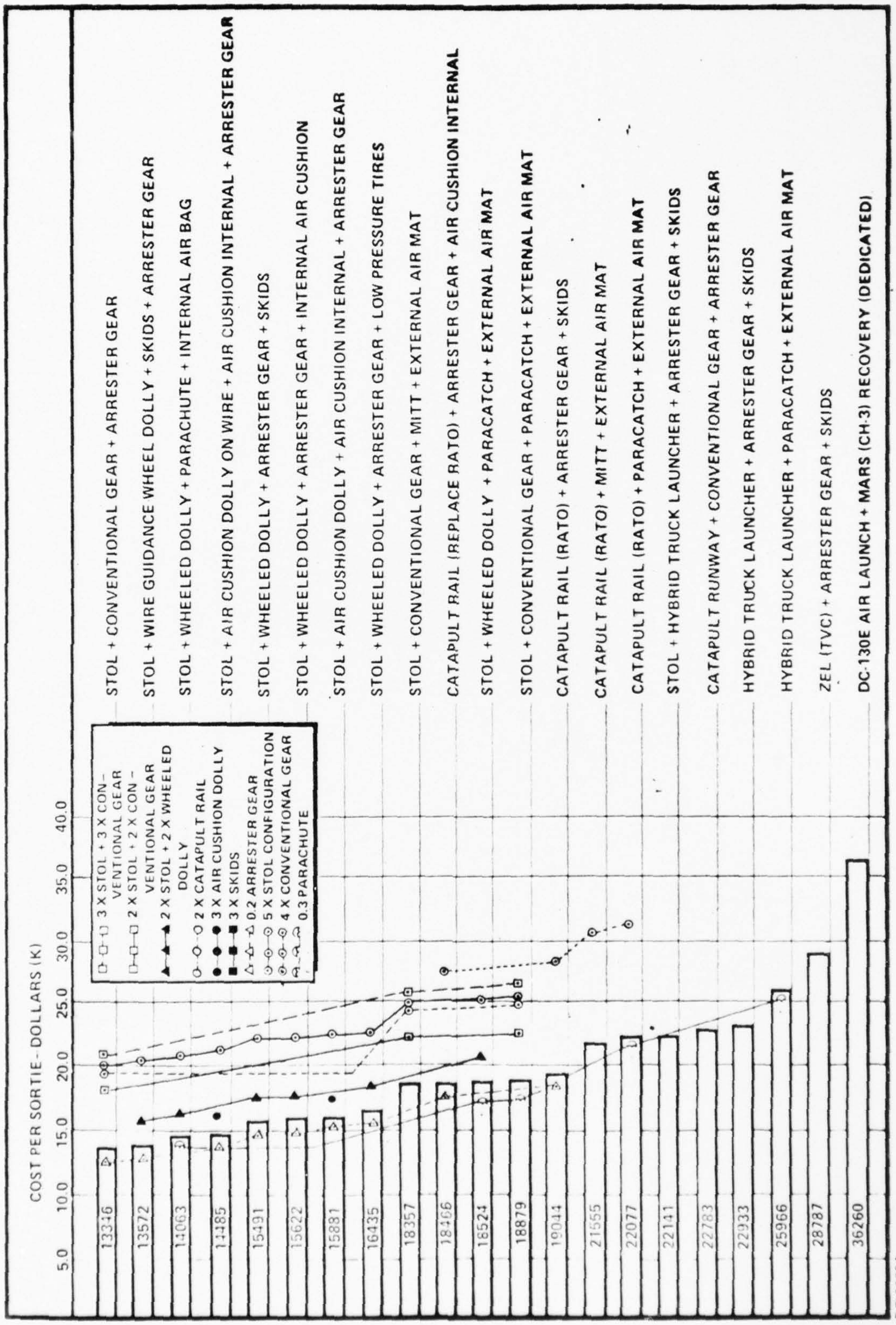

Figure 5.2-1. Cost Ranking of Matched Systems

The STOL configuration emerged as a potentially attractive system because it can be utilized with the majority of launch and recovery techniques. The cost estimates are based upon assumption that STOL performance of the ARPV can be obtained without internal blowing with associated engine/airframe complications and without complex cascaded airfoil design as usually is the case. A simple geometry of leading edge droop and plain trailing edge droop mechanization appears to promise a sufficient Δ CL gain to give ARPV a significant reduction in launch and recovery velocities. This reduction, in turn, results in much lower kinetic energy demands either for propulsion or arrestment in these two critical phases of the mission.

The highest cost system was the present air launch method by DC-130 with MARS recovery when dedicated carriers are used.

5.3 SENSITIVITY ANALYSIS

A sensitivity analysis was performed next to determine how does the cost per sortie vary with the increase in the estimated cost of some selected building blocks when considered either separately or in conjunction with each other. The modified cost lines can be seen just above the histogram and the associated legend is attached thereto.

The sensitivity analysis tends to indicate that the present launch and recovery methods are very costly and stand well above some of the more excessive cost predictions of other systems that can be made at the present.

5.4 REVISION AND UPDATE OF COST DATA

The cost data in Table 5.2-1 and Figure 5.2-1, reflecting the cost of the elements and the complete matched systems, respectively, was being updated with the new information from the vendors. Table 5.4-2 presents new figures on some of the system elements, and in addition, introduces several new system component elements which were not shown in the original table. These are: arrester barrier, airfield matting AM2, arrester hook, new ARPV dedicated catapult and a modified SATS catapult. Efforts were made to obtain new data on all L&R elements listed in Table 5.2-1. Some still remained just guessed estimates particularly in the areas where only paper concepts were addressed. If upon revision any concept did not introduce a significant change in the cost per sortie estimates, it was left unaltered from the values established in the original table as it would most likely have little effect on the outcome of the final rating.

The big changes were in the cost per sortie of ARRESTER GEAR which changed from original figure of $5044 per sortie to $1231 per sortie and in the concept using modified SATS catapult assuming the primary equipment was available from inventory at no cost, and only cost of modifications was counted. (This type of approach was considered valid only in a case where the equipment was obtained from another branch of service. It could not be applied to DC-130 and HH 53 in the air launch and recovery mode because the charges for their use were leveled directly against the Air Force Appropriations.)

In assessing the impact of the new data on the cost per sortie of each matched system, a new set of figures was derived for systems which were directly affected by the new data. The counting tables are shown below for each of these systems under their respective titles.

Table 5.4-2 Cost Matrix of L&R Building Blocks
(Update of Data)

	ACQ COST INCLUDING RDT&E PER UNIT	REPLACE FACTOR	BASIC LOGISTIC SUPPORT	TOTAL SUPPORT COST	OPERAT. COST	NO. OF UNITS PER SQUADRON	NO. PER FORCE	BASIC LIFE CYCLE COST	AUXIL. EQUIP COST PER FORCE	FACIL. COST PER FORCE	SINGLE LRR COST	COST PER 4500 SORTIES	ADDITIONAL LOGISTIC COST	VEHICLE INTERNAL AVION. COST	EXTERNAL AVIONICS COSTS	GRAND TOTAL LIFE CYCLE COST	COST PER SORTIE (4500's)
ARRESTER GEAR	34K	1.2	17K	20.4K	17K	2	18	1.29M	INCL. WITH RECOVERY EQUIPMENT		0.5K	2.25M	2.0M	NIL	INCL WITH TAKEOFF	5.54M	1231
ARRESTER BARRIER	40K	1.5	20K	30K	20K	4/3	12	1.08M	INCL. WITH RECOVERY EQUIPMENT		0.2K	0.9M	1.0M	NIL	INCL WITH TAKEOFF	2.98M	662
AIRFIELD MATTING AM2	0.008K/f^2	1.2	0.004K/f^2	0.0048K/f^2	0.004K/f^2	50,000 SQ.FT.	450,000 SQ. FT	7.56M	-	-	NIL	NIL	2.0M	NIL	NIL	9.56M	2124
AIR BAGS INTERNAL	10K	1.5	5K	7.5K	5.0K	50	450	10.1M	-	-	0.5K	2.25M	1.0M	NIL	NIL	13.35M	2966
PARACHUTE WITH DEPLOYMENT MORTAR	12K	1	6K	6K	6K	50	450	10.8M	-	-	0.5K	2.25M	2.0M	3K x 450 = 1.35M	NIL	16.4M	3644
AIR MAT EXTERNAL FOR MITT OR PARA-CATCH	150K	2.0	75K	150K	75K	2	18	6.75M	-	-	0.2K	0.9M	1.0M	-	-	8.65M	1922
NEW ARPV CATAPULT (SATS)	3.0M	1.0	1.5M	1.5M	1.5M	1	3 PER BASE 9	54.0M	-	-	0.5K	2.25M	3.0M	-	-	59.25M	13166
SATS CATAPULT (MODIFIED)	0.8M	1.0	0.4M	0.4M	0.4M	1	3 PER BASE 9	14.4M	-	-	0.5K	2.25M	3.0M	-	-	19.65M	4366
ARRESTER HOOK INSTALLATION	1.6K	2.0	0.8K	1.6K	0.8K	50	450	1.8M	-	-	-	-	-	-	-	1.8M	400
HIGH FLOATATION 3 WHEEL GEAR	20K	1.2	10K	12K	10K	50	450	18.9M	TOW JEEPS 20K x 10 x 9 = 1.8M	SEE MATTING	0.2K	0.9M	-	15K x 450 = 6.75M	18 x 250K = 4.5M	32.85M	7293

It should be noted that while the cost of vehicle arresting came down rather drastically, the new elements that were not listed in Table 5.2.1 (arrester barrier, hook and field matting) introduced new costs and had, therefore, an allevating effect on big cost reduction in systems using arresting gear.

A revised "low cost" part of histogram is shown in Figure 5.4-1 . It can be seen that updating of cost data resulted in relatively minor changes in this part of histogram. A major one was the placement of WHEELED STEERED DOLLY + STOL + ARR. GEAR + INTERNAL AIR CUSHION (used only for landing) in the second position behind the conventional gear concept. Previously the wheeled dolly concept was rated 6th in terms of cost. Another shift from costly L & R method to the low cost was registered by a SATS catapult system SATS(MODS) where only the modification to the present system was costed (from 17th to 6th position). If, however, a new catapult is designed for this system, then the expected life cycle cost per sortie would move from $16K to $25K category.

5.5 COUNTING TABLES

STOL + CONVENTIONAL GEAR + ARRESTER GEAR

	NEW	ORIGINAL
High Floatation 3 Wheel Gear Incl. M.L.S.	7,293	6,511
STOL Configuration	1,791	1,791
ARRESTER GEAR	1,231	5,044
HOOK	400	-
ARRESTER BARRIER	662	-
AIRFIELD MATTING	2,124	-
	$13,501	$13,346

STOL + WIRE GUIDANCE WHEEL DOLLY + SKIDS + ARRESTER GEAR

	NEW	ORIGINAL
STOL	1,791	1,791
WHEELED DOLLY (WIRE GUIDANCE)	4,237	4,237
SKIDS	2,500	2,500
ARRESTER GEAR	1,231	5,044
HOOK	400	-
ARRESTER BARRIER	662	-
FIELD MATTING	2,124	-
MLS to be added	2,500	-
	$15,445	$13,572

STOL + WHEELED DOLLY + PARACHUTE + INTERNAL AIR BAG

	NEW	ORIGINAL
STOL	1,791	1,791
WHEELED DOLLY	6,156	6,156
PARACHUTE	3,644	3,244
INTERNAL AIR BAGS	2,966	2,872
	$14,557	$14,063

STOL + WHEELED DOLLY + ARRESTER GEAR + INTERNAL AIR CUSHION

	NEW	ORIGINAL
STOL	1,791	1,791
WHEELED DOLLY (STEERABLE)	6,156	6,156
ARRESTER GEAR	1,231	5,044
INTEGRAL AIR CUSHION	1,922	1,922
ARRESTER BARRIER	662	-
FIELD MATTING	2,124	-
MLS	(Incl. MLS)	(Incl. MLS)
HOOK	400	
	$14,286	$14,913

STOL + CONVENTIONAL GEAR + SATS CATAPULT(MOD) + ARRESTER GEAR

	NEW	ORIGINAL
STOL	1,791	1,791
CONVENTIONAL GEAR	7,293	6,511
SATS CATAPULT(MOD)	4,366	11,228
ARRESTER GEAR	1,231	5,044
HOOK	400	-
ARRESTER BARRIER	662	-
AIRFIELD MATTING	2,124	-
	$17,867	$24,574

STOL + AIR CUSHION DOLLY ON WIRE + AIR CUSHION INTERNAL + ARRESTER GEAR

	NEW	ORIGINAL
STOL	1,791	1,791
AIR CUSHION DOLLY ON WIRE	4,528	4,528
ALLS	1,922	1,922
ARRESTER GEAR	1,231	5,044
HOOK	400	-
ARRESTER BARRIER	662	-
AIRFIELD MATTING	2,124	-
MLS	2,500	1,200 (only added)
	$15,158	$14,485

STOL + WHEELED DOLLY + ARRESTER GEAR + SKIDS

	NEW	ORIGINAL
STOL	1,791	1,791
WHEEL DOLLY	6,156	6,156
SKIDS	2,500	2,500
ARRESTER GEAR	1,231	5,044
HOOK	400	-
ARRESTER BARRIER	662	-
FIELD MATTING	2,124	-
MLS	2,500	(No MLS)
	$17,364	$15,491

ZEL (TVC) + DUAL MODE PARACHUTE + AIR BAG

	NEW	ORIGINAL
ZEL(TVC) LAUNCH	21,243	21,243
AIR BAG INTEGRAL	2,966	2,872
DUAL MODE PARACHUTE	3,644	3,244
	$27,853	$27,359

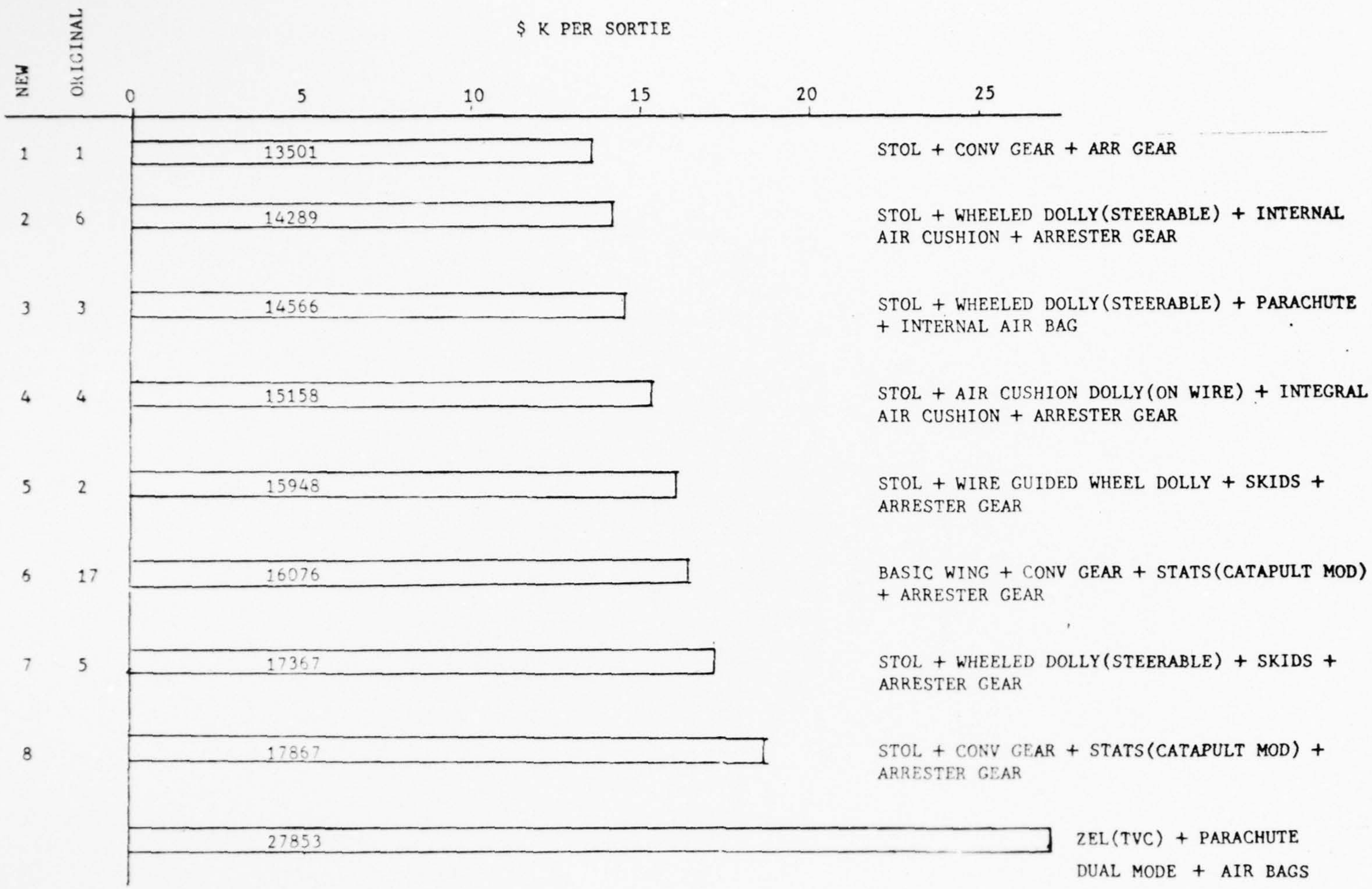

Figure 5.4-1. Histogram of Revised Cost Data for Selected Matched Systems

6.0 SYNTHESIS OF TRADE-OFF ANALYSES

6.1 SELECTION OF FINALISTS

The iterative process of selection and cost evaluation of potential systems presented in preceding sections leads logically to the final phase of TRADE STUDIES - namely, the COST/BENEFITS/RISK Analysis. For this purpose the finalist systems were selected on the basis of the following criteria:

(a) cost per sortie, (b) capability to sustain high sortie rates, (c) instant mobility, (d) flexibility, (e) small field requirements, (f) minimum demand for off-vehicle equipment, (g) inherent survivability, and (h) logistics requirements.

To the seven systems, which became finalists, three existing systems (operational and under development) were added for competitive evaluation.

The list of the 10 systems so selected is given below. (See Appendix pages A-38 to A-48 for concept development.) In this list the STOL system continues to describe a high lift airfoil configuration without blowing.

1. STOL + CONVENTIONAL GEAR + ARRESTER GEAR
2. STOL + WIRE GUIDANCE WHEEL DOLLY + ARRESTER GEAR + SKIDS/AIR BAGS
3. CATAPULT (SATS MOD) + CONVENTIONAL GEAR + ARRESTER GEAR(NO STOL)
4. STOL + HYBRID TRUCK LAUNCHER + ARRESTER GEAR + SKIDS/AIR BAGS
5. STOL + WHEELED DOLLY(STEERABLE) + ARRESTER GEAR + INTEGRAL AIR CUSHION
6. STOL + CATAPULT (SATS MOD) + CONVENTIONAL GEAR + ARRESTER GEAR
7. ZEL (TVC) + DUAL MODE PARACHUTE + AIR BAGS (SYSTEM USED BY BGM SERIES)
8. STOL + AC DOLLY(DROPPABLE) + INTEGRAL AIR CUSHION + ARRESTER GEAR (VARIANT OF JINDIVIK SYSTEM)
9. AIR LAUNCH BY DC-130 H - MARS RECOVERY BY HELICOPTER
10. CATAPULT RAIL(RATO) + MITT + EXTERNAL AIR MAT

Table 6.1-1 presents the positive and the negative aspects relating to the application of the selection criteria which resulted in the above list. It should be noted that these (aspects) were based on the analyses presented in Sections 3.0 and 4.0 of this report as they were applicable to each of the matched system that were costed for the final analysis. Table 6.1-1 shows that the CATAPULT/MITT concept did not satisfy a number of the criteria set out for final selection. It was, however, included in the final list because it is the only matched system which places minimum demands on the vehicle for both the launch and the recovery. For the latter case, it only calls for a reasonable accuracy of the airborne vehicle impact at loiter speeds within the MITT netting lattics. This last consideration places the MITT system as a potential last resort recovery for all vehicles in the holding pattern that could still maintain flight integrity but could not possibly survive any other recovery technique. In this last concept, the MITT recovery system could operate in conjunction with any other system that might be selected for the ARPV.

6.2 OPERATIONAL ASSESSMENT OF FINAL CANDIDATE SYSTEMS

For this assessment a new list of quantifiable descriptors was established designed to be predominently responsive to the operational aspects of the system. These descriptors were generally different for launch (26) and recovery (21) although several of them were similar.

The weighting factors were allocated to each descriptor and the individual rating was again based on the scale ratings that were assigned to P.O.E.D. The operational rating was made separately for the launch and the recovery, and the resulting assessment sheets are presented in Table 6.2-1 (Launch) and Table 6.2-2 (Recovery). Each matrix contains, adjacent to its rating, a weighting factor with a short description of the prevailing reason for the assessment.

Table 6.1-1 Selection Criteria For Cost/Benefit/Risk Analysis

	COST PER SORTIE	HIGH SORTIE RATES	INSTANT MOBILITY	FLEXIBILITY	SMALL FIELD REQUIREMENTS	MINIMUM OFF VEHICLE EQUIPMENT	INHERENT SURVIVABILITY	LOGISTICS REQUIREMENTS	RATIO	SELECTED SYSTEMS
STOL + CONVENTIONAL GEAR + ARRESTER GEAR	+	+	+	-	+	-	+	+	6:2	✓
STOL + WIRE GUIDANCE WHEEL DOLLY + SKIDS + ARRESTER GEAR	+	+	+	-	+	-	+	+	6:2	✓
STOL + WHEELED DOLLY + PARACHUTE + INTERNAL AIR BAG	+	+	-	-	+	-	-	-	3:5	
STOL + AIR CUSHION DOLLY ON WIRE + AIR CUSHION INTERNAL + ARRESTER GEAR	+	-	-	+	+	-	-	-	3:5	
STOL + WHEELED DOLLY + ARRESTER GEAR + SKIDS	+	+	+	-	+	-	+	+	6:2	✓
STOL + WHEELED DOLLY + ARRESTER GEAR + INTERNAL AIR CUSHION	+	+	-	+	+	-	-	+	5:3	✓
STOL + AIR CUSHION DOLLY + AIR CUSHION INTERNAL + ARRESTER GEAR	+	-	-	+	+	-	-	-	3:5	
STOL + WHEELED DOLLY + ARRESTER GEAR + LOW PRESSURE TIRES	+	+	+	-	+	-	-	-	4:4	
STOL + CONVENTIONAL GEAR + MITT + EXTERNAL AIR MAT	-	+	+	-	+	-	+	-	4:4	
CATAPULT RAIL (REPLACE RATO) + ARRESTER GEAR + AIR CUSHION INTERNAL	-	-	-	+	+	-	-	-	2:6	
STOL + WHEELED DOLLY + PARACATCH + EXTERNAL AIR MAT	-	+	-	-	+	-	-	-	2:6	
STOL + CONVENTIONAL GEAR + PARACATCH + EXTERNAL AIR MAT	-	+	+	-	+	-	-	-	3:5	
CATAPULT RAIL (RATO) + ARRESTER GEAR + SKIDS	-	+	-	-	+	-	+	+	4:4	
CATAPULT RAIL (RATO) + MITT + EXTERNAL AIR MAT	-	-	-	+	+	-	+	-	3:5	✓
CATAPULT RAIL (RATO) + PARACATCH + EXTERNAL AIR MAT	-	-	-	-	+	-	-	-	1:7	
STOL + HYBRID TRUCK LAUNCHER + ARRESTER GEAR + SKIDS	-	+	+	+	+	-	+	-	5:3	✓
CATAPULT RUNWAY + CONVENTIONAL GEAR + ARRESTER GEAR	-	+	+	-	+	-	+	+	5:3	✓
HYBRID TRUCK LAUNCHER + ARRESTER GEAR + SKIDS	-	+	+	+	+	-	-	-	4:4	
HYBRID TRUCK LAUNCHER + PARACATCH + EXTERNAL AIR MAT	-	-	-	-	+	-	-	-	1:7	
ZEL (TVC) + ARRESTER GEAR + SKIDS	-	-	+	+	+	-	+	-	4:4	
DC-130E AIR LAUNCH + MARS (CH-3) RECOVERY (DEDICATED)	-	-	-	+	+	-	+	-	3:5	

Table 6.2-1. Operational Assessment (Laun

WEIGHTING FACTORS	SYSTEM LAUNCH DESCRIPTOR	1: STOL + CONVENTIONAL GEAR + ARRESTER GEAR	BASIC RATING	WEIGHTED RATING	2: ZEL + TVC + DUAL MODE PARACHUTE + AIR BAG	BASIC RATING	WEIGHTED RATING	3: STOL + WHEELED DOLLY (WIRE GUIDANCE) + ARRESTER GEAR + SKIDS (WITH AIR BAGS)	BASIC RATING	WEIGHTED RATING	4: STOL + AIR CUSHION DOLLY + ARRESTER GEAR + INTEGRAL AIR CUSHION	BASIC RATING	WEIGHTED RATING	5: CATAPULT RUNWAY CONVENTIONAL GEAR ARRESTER GEAR (NO STOL)	BASIC RATING	WEIGHTED RATING
10	REACTION TIME FROM "GO"	GOOD. VEHICLES MUST BE EMPLACED FOR LAUNCH.	6	60	EXCELLENT. VEHICLE ON STANDS–IN POSITION READY TO GO.	7	70	FAIR. VEHICLES MUST BE EMPLACED ON DOLLIES FOR LAUNCH.	4	40	FAIR TO POOR. RPVs MUST BE PLACED ON DOLLIES DOLLIES CHECKOUT REQUIRED.	3	30	FAIR. ENERGY STORING DEVICES REQUIRE TIME TO SPIN.		
6	INITIAL LAUNCH RATE (FIRST 4 HRS)	GOOD. DEPENDS ON NUMBER OF VEHICLES INITIALLY AVAILABLE.	6	36	EXCELLENT. DEPENDS ON NUMBER OF READY LAUNCHERS ON SITE.	7	42	GOOD TO FAIR. DEPENDS ON NO. OF DOLLIES PER UNIT.	5	30	GOOD TO FAIR. DEPENDS ON NO. OF DOLLIES PER SITE.	4	24	FAIR. CATAPULT LAUNCH RATE DEPENDS ON ENERGY RECUPERATION.		
10	SUSTAINED LAUNCH RATE	GOOD. DEPENDS ON TURNAROUND TIME.	6	60	FAIR TO POOR. DEPENDS ON TURN-AROUND AND LAUNCHER.	3	30	GOOD TO FAIR. VEHICLES MUST BE PLACED ON DOLLIES ON SITE.	4	40	FAIR TO POOR AIRCRAFT DOLLY RETRIEVAL AND REMOUNTING DIFFICULT.	3	30	POOR TO FAIR. DEPENDS ON RESTORING ENERGY SYSTEM.		
6	RECYCLE REQUIREMENTS	NOSE WHEEL DIRECTOR MUST BE RECYCLED IF USED FOR HEAD HOLD.	4	24	NONE. ALL SELF-CONTAINED SYSTEM.	7	42	REQUIRED. DOLLIES MUST BE RECOVERED OR RECYCLED AFTER TAKE OFF.	3	18	REQUIRED. AIRCRAFT DOLLIES HAVE TO BE RECYCLED.	3	18	SHUTTLE NEEDS RECYCLING AFTER EACH LAUNCH.		
10	CONTRIBUTION TO TURNAROUND TIME	VERY SMALL. VEHICLES ARE READY AFTER TOW IN AND OUT.	6	60	POSSIBLY SERIOUS. LAUNCHER SET UP AND CHECKOUT MUST BE INCLUDED.	4	40	SERIOUS. RPVs ARE TRANSFERRED BY CRANE FROM TRANSPORTS TO DOLLIES.	3	30	SERIOUS. RPVs HAVE TO BE TRANSFERRED FROM TRANSPORT.	3	30	CATAPULT INSERTION IS SIMPLE AND CAN BE FAST.		
6	MOBILITY OF SET UP AND WIND DOWN	EXCELLENT. ONLY LIMITED EQUIPMENT IS INVOLVED.	7	42	EXCELLENT. REMOVE AND TOW AWAY LAUNCHERS.	7	42	COMPLEX. RPVs ON DOLLIES MUST BE TRANSFERRED TO TRANSPORT VEHICLES.	3	18	COMPLEX. TOWING NOT POSSIBLE. RPVs MUST BE TRANSFERRED.	3	18	VERY POOR. RUNWAY CATAPULTS ARE PERMANENT FIXTURES.		
6	ALIGNMENT WITH WIND REQMTS	AVERAGE. MUST ALIGN WITH PREVAILING WIND DAILY.	4	24	EASY. ALIGN LAUNCHER INTO WIND FOR SAFETY.	6	36	AVERAGE. MUST ALIGN WITH PREVAILING WIND DAILY.	4	24	VERY CRITICAL. AIRCRAFT DOLLIES ARE SUSCEPTIBLE TO X WINDS.	3	18	NOT REQUIRED IF TAKE OFF SPEED IS MET THEN WINDS DON'T MATTER.		
6	ATTITUDE CONTROL REQMTS	REQUIRED AT NOSE LIFTOFF SPEED.	3	18	ESSENTIAL. TVC PROVIDES ATTITUDE CONTROL.	3	18	NOT REQUIRED UNTIL LIFT-OFF SPEED. JUST GET AWAY FROM DOLLY.	6	36	NOT REQUIRED UNTIL LIFTOFF–SPEED.	6	36	NOT REQUIRED UNTIL RELEASE FROM CATAPULT.		
6	HEADING HOLD REQMTS	REQUIRED THROUGHOUT GROUND RUN UNTIL LIFTOFF SPEED.	3	18	ESSENTIAL. TVC PROVIDES HEAD HOLD INITIALLY.	3	18	PROVIDED BY WIRE HEADING CONTROL.	5	30	PROVIDED BY TAIL PIPE HEADING CONTROL.	6	36	NOT REQUIRED. CATAPULT HEADING IS HELD DURING RUN.		
6	GROUND CONTROL REQMTS	REQUIRED DURING COMPLETE TAKE OFF RUN.	3	18	REQUIRED. DURING COMPLETE LAUNCH CYCLE.	3	18	REQUIRED. DURING FINAL STAGES OF LIFT OFF.	3	18	REQUIRED. DURING FINAL STAGES OF LIFTOFF.	3	18	REQUIRED IMMEDIATELY AFTER LAUNCH.		
6	"G" LEVELS DURING LAUNCH	VERY LOW. 0.5–0.7 "G" DEPENDING ON T/W RATIO.	4	24	LOW TO MODERATE. "G" DEPENDS ON BOOST T/W RATIO.	4	24	VERY LOW. 0.5–0.7 DEPENDING ON T/W OF PROPULSION/WEIGHT.	4	24	VERY LOW. DEPENDING ON T/W OF SYSTEM.	4	24	MODERATE TO HIGH. DEPEND ON CATAPULT STROKE.		
6	ABORT TOLERANCE	VERY GOOD. CAN ABORT AT ANY POINT OF GROUND RUN.	6	36	VERY POOR. CAN DO NOTHING ONCE RATO LIT UP OCCURS.	2	12	VERY GOOD. CAN ABORT ANY TIME DURING GROUND RUN.	6	36	VERY GOOD. CAN ABORT AT ANY TIME DURING TAKE OFF RUN.	6	36	ABORT NOT POSSIBLE ONCE ACTION STARTED. VEHICLE HAS TO GET AIRBORNE.		
10	MISSION RANGE EFFECTS	AVERAGE WEIGHT OF GEAR 150 LBS. VOLUME LOST 8.3 CU FT.	4	40	GOOD TO AVERAGE. PRESENCE OF PARACHUTE COUNTERACTS LOSS OF GEAR.	4	40	GOOD. SKIDS ARE LIGHTER THAN LANDING GEAR.	5	50	TOTAL AIRCRAFT SYSTEM INTERNAL WEIGHT WILL BE PROBABLY LIGHT.	5	50	AS PER COLUMN 1 LANDING GEAR WEIGHS 150 LBS.		
6	GROUND SUPPORT EQUIPMENT	VERY LOW. TOW BAR JEEPS CHOCKS AND GROUND MOORING.	6	36	POOR. REQUIRES TOWABLE LAUNCHERS LIFTING EQUIPMENT.	2	12	POOR. LIFTING EQUIPMENT PLUS TRANSPORT EQUIPMENT REQUIRED.	3	18	COMPLEX. CRANE TRANSPORTERS. DOLLY TOWERS AND PRESSURIZERS.	3	18	VERY LOW. TOW BARS AND JEEPS TO TOW RPVs REQUIRED.		
6	"AFTER LAUNCH" EQUIPMENT AND RECOVERY	CLEAN AND RECYCLE HEADING CONTROL DIRECTOR.	4	24	RATO MOTORS DROP OFF. NEED SAFETY HANDLING.	4	24	DOLLY NEEDS TO BE RECOVERED UNDAMAGED.	2	12	DOLLY MUST BE RETURNED UNDAMAGED TO LAUNCH POINT.	2	12	NIL. SHUTTLE RETURN IS OR CAN BE AUTOMATIC.		
3	LAUNCH EFFECTS ON EQUIPMENT	NEGLIGIBLE. ESSENTIALLY NO EFFECT.	6	18	VERY BAD. HEAT AND CORROSION DISTORTION FUMES.	1	3	NEGLIGIBLE EXCEPT OF POSSIBLE DAMAGE OF HARD POINTS.	4	12	NEGLIGIBLE. EXCEPT IF AIR PRESSURE FAILS.	3	9	POSSIBLE DAMAGE CAN RESULT FROM FAILED CABLES WHIPS.		
6	ACCESS TO VEHICLE DURING LAUNCH	EXCELLENT. VEHICLE STAYS ON WHEELS AT GROUND LEVEL.	7	42	VERY POOR. VEHICLE IS NORMALLY INACCESSIBLE DURING LAUNCH.	2	12	AVERAGE. DOLLY BLOCKS CERTAIN VEHICLE PARTS DURING TAKE OFF PREPARATION.	4	24	POOR. DOLLY ENVELOPE PREVENTS DIRECT ACCESS TO RPV.	3	18	VERY GOOD. SOME EXTRA CARE NEEDED BECAUSE OF CATAPULT.		
10	SAFETY OF PERSONNEL	VERY GOOD. NO FUMES NO HIGH HOT GAS JETS AND DEBRIS.	6	60	POOR. SELF IGNITION OF RATO OR BURNS POSSIBLE.	2	20	VERY GOOD. SIMPLE OPERATION NO FUMES AND DEBRIS DURING TAKE OFF.	6	60	GOOD. EXCEPT WHEN AIR PRESSURE IN DOLLY FAILS.	4	40	AVERAGE. CATAPULTS EQUIPMENT REQUIRES SPECIAL CARE (WHIPS).		
6	MANPOWER PER LAUNCH SITE REQMT	AVERAGE. 3 MEN PER VEHICLE. 2 MEN IN CONTROL STATION.	5	30	AVERAGE. 3 MEN PER VEHICLE. 2 MEN IN CONTROL STATION.	5	30	MORE THAN AVERAGE. UP TO 5 MEN REQD FOR TRANSFER AND ALIGNMENT.	3	18	MORE THAN AVERAGE. AT LEAST 7 PEOPLE MAY BE REQUIRED.	3	18	EXCESSIVE. CATAPULT AND VEHICLE HANDLING PEOPLE ARE REQUIRED.		
6	SKILL LEVELS RATIO	AVERAGE. 2 X (3) 2 X (5) 1 X (7).	5	30	AVERAGE 4 X (5) 1 X (7).	5	30	AVERAGE 3 X (3) 2 X (5) 1 X (7).	4	24	AVERAGE. 4 X (3) 3 X (5) 1 X (7).	3	18	AVERAGE TO HIGH. 6 X (3) 3 X (5) 1 X (7).		
10	ALL WEATHER COMPATIBILITY	VERY GOOD. CAN OPERATE IN LOW LEVEL OF VISIBILITY–ALL CLIMATES.	6	60	VERY GOOD. OPERATES ALL WEATHER ALL CLIMATES (APPX).	6	60	GOOD–AVERAGE. DOLLY MORE AFFECTED BY SNOW AND MUD.	5	50	VERY GOOD. CAN TAKE OFF ON SNOW. MUD. WATER. ALL VISIBILITIES.	6	60	VERY GOOD. CAN OPERATE IN ANY WEATHER		
10	SURVIVABILITY AT LAUNCH	GOOD. USING STOL VEHICLE SHOULD HAVE GOOD SURVIVABILITY.	5	50	GOOD. WITH TVC ONBOARD.	5	50	GOOD TO AVERAGE. CRITICAL POINT IS THE DOLLY VEHICLE SEPARATE.	5	50	AVERAGE. X WIND EFFECTS ON DOLLY AND DOLLY PRESSURE CRITICAL.	3	30	HIGH LEVEL OF SURVIVALS EXPECTED FROM CAT. LAUNCH.		
6	LAUNCH DISTANCE	MODERATE. UP TO 1500 FT REQUIRED FOR TAKE OFF.	3	18	VERY SMALL. BUT REAL ESTATE REQUIRED FOR MOTORS DROP OFF.	3	18	MODERATE. UP TO 1500 FT REQUIRED.	3	18	LONG. DOLLY GROUND DRAG MAY BE HIGH ON EVERYTHING EXCEPT RUNWAY.	3	18	MODERATE. REQUIRE NEARLY SAME DISTANCE AS PER STOL.		
6	LAUNCH SURFACE REQMTS	PREPARED. MATTING OR FIRM EVEN GROUND LOW CBR VALVE–4 APPX.	5	30	EXCELLENT. ANY LEVEL GROUND IS SATISFACTORY.	7	42	PREPARED. MATTING OR FIRM GROUND REQUIRED.	5	30	PREPARED TO UNPREPARED. LOTS OF DIFF SURFACE LEVELS ACCEPT.	6	36	PREPARED. MATTING PREFERRED.		
6	SPECIAL EQUIPMENT REQUIRED	REQUIRED. TAKE OFF HEADING DIRECTOR MECHANICAL OR ELECTRIC.	3	18	NONE. EXCEPT FOR RATO BOTTLES HEAT DEFLECTOR AND LAUNCH.	7	42	REQUIRED. STEERED OR WIRE CONTROLLED DOLLIES WITH EQUIPMENT.	3	18	REQUIRED. AIR PRESSURED DOLLIES LIFT AND TRANSPORTERS.	3	18	CATAPULT AND BRIDDLES WITH SUPPORT EQUIPMENT REQUIRED.		
10	VULNERABILITY (ENEMY ACTION)	BETTER THAN AVERAGE. DISPERSAL. CAMOUFLAGE ONLY LAUNCH SITE VULNERABLE.	5	50	AVERAGE. DISPERSAL. CAMOUFLAGE. BUT BOTH VEHICLE AND LAUNCHER VULNERABLE.	4	40	AVERAGE. RPVs DISPERSAL IS MORE COMPLICATED.	3	30	VULNERABLE. PENETRATION OF AIRCRAFT BAGS CRITICAL.	2	20	VULNERABLE. IF CATAPULT DAMAGED OPERATIONS WILL STOP.		
	Σ OF WEIGHTED FACTOR = 185	Σ = 926 FOM = 5.00			Σ = 815 FOM = 4.40			Σ = 758 FOM = 4.09			Σ = 683 FOM = 3.69			Σ FOM		

2

Assessment (Launch) of Finalist Systems

BASIC RATING / WEIGHTED RATING	CATAPULT RUNWAY + CONVENTIONAL GEAR + ARRESTER GEAR (NO STOL)	BASIC RATING	WEIGHTED RATING	AIR LAUNCH BY DC-130H RECOVERY BY MARS (HH53) HELICOPTER	BASIC RATING	WEIGHTED RATING	HYBRID TRUCK LAUNCHER PLUS STOL + ARRESTER GEAR + SKIDS	BASIC RATING	WEIGHTED RATING	CATAPULT RAIL (RATO) + MITT + EXTERNAL AIR MAT	BASIC RATING	WEIGHTED RATING	CATAPULT (RUNWAY-SATS) + STOL + CONVENTIONAL GEAR + ARRESTER GEAR	BASIC RATING	WEIGHTED RATING	STOL + WHEELED DOLLY (STEERABLE) + ARRESTER GEAR + INTEGRAL AIR CUSHION	BASIC RATING	WEIGHTED RATING
	5			6			7			8			9			10		
30	FAIR. ENERGY STORING DEVICES REQUIRE TIME TO SPIN.	2	20	FAIR. RPVs ARE TO BE LOADED ON PYLONS AND CHECKED OUT.	3	30	FAIR TO GOOD. RPVs ARE LOADED ON LAUNCHERS.	4	40	FAIR TO GOOD. RPVs MUST BE PLACED ON RAIL CATAPULT AND CHECKED OUT.	4	40	POOR TO FAIR. ENERGY STORING DEVICES REQUIRE TIME TO SPIN.	3	30	FAIR. EMPLACEMENT ON DOLLIES REQUIRED.	4	40
24	FAIR. CATAPULT LAUNCH RATE DEPENDS ON ENERGY RECUPERATION.	3	18	EXCELLENT TO VERY GOOD. DEPENDS ON NO. OF LAUNCH AIRCRAFT.	6	36	FAIR TO GOOD. DEPENDS ON NO. OF LAUNCH TRUCKS.	4	24	FAIR TO GOOD. DEPENDS ON NO. OF RAIL CATAPULTS ON SITE.	4	24	FAIR. CATAPULT'S RATE DEPENDS ON ENERGY RECUPERATION.	3	18	FAIR TO GOOD. DEPENDS ON NO. OF VEHICLES EMPLACED.	5	30
30	POOR TO FAIR. *DEPENDS ON RESTORING* ENERGY SYSTEM.	3	30	VERY POOR. TURNAROUND *AND BASING CONSIDERA-*TIONS ARE LIMITING.	1	10	MODERATE. PROBLEM *IS RATO MOTOR CHANGE* AND SECURING RPV.	3	30	MODERATE. PROBLEMS ARE IN CATAPULT RECHARGE AND RPV CHECKOUT.	3	30	FAIR. DEPENDS ON RATE OF ENERGY RESTORING.	3	30	FAIR. TURNAROUND BETWEEN ACLS AND DOLLIES POOR.	3	30
18	SHUTTLE NEEDS RECYCLING AFTER EACH LAUNCH.	3	18	NONE. CHECKOUT OF LAUNCH PYLONS AND EQUIPMENT.	6	36	REQUIRED. SHUTTLE NEEDS RECYCLING AND MOTORS REPLACED.	3	18	REQUIRED. SHUTTLE NEEDS RECYCLE AND MOTOR REPLACED.	3	18	SHUTTLE NEEDS RECYCLING AFTER EVERY LAUNCH.	3	18	REQUIRED. DOLLY MUST BE RECYCLED AFTER LAUNCH.	3	18
30	CATAPULT INSERTION IS SIMPLE AND CAN *BE FAST.*	5	50	VERY HIGH. MOST OF AIRCRAFT CHECKS AFTER *LAUNCH ARE CRITICAL.*	2	20	SERIOUS. PROBLEMS ARE SUSPENSION OF RPV AND CHECKOUT.	2	20	SERIOUS PROBLEMS ARE SUSPENSION OF THE RPV AND CHECKOUT.	2	20	SMALL. CATAPULT INSERTION IS SIMPLE AND CAN BE FAST.	5	50	SERIOUS. RPVs MUST BE TRANSFERRED BETWEEN DOLLY AND A/CLS.	3	30
18	VERY POOR. RUNWAY CATAPULTS ARE PERMANENT FIXTURES.	1	6	COMPLEX. THE SUPPORT SYSTEM TO OPERATE AIRCRAFT AND RPVs IS LARGE.	2	12	EXCELLENT. PACK UP AND DRIVE AWAY RPVs FOLLOW ON FLAT BEDS.	7	42	POOR. LONG TIME REQUIRED TO WIND DOWN OR SET UP R CAT.	2	12	POOR. RUNWAY CATAPULTS ARE PERMANENT FIXTURES.	1	6	COMPLEX. INTERPLAY BETWEEN DOLLIES AND FLAT BEDS.	3	18
18	NOT REQUIRED IF TAKE-OFF SPEED IS MET THEN WINDS DON'T MATTER.	7	42	NONE. RPVs ARE AIR LAUNCHED.	7	42	EASY—ORIENT AND ALIGN TRUCK HEADING WITH WIND.	7	42	POOR. ONCE SETUP CATAPULT WILL STAY AS IS.	2	12	NOT REQUIRED. CATAPULT STROKE TAKES CARE OF WIND EFFECTS.	7	42	AVERAGE. PREFERRED FUNCTION WHEN ALIGNED.	4	24
36	NOT REQUIRED UNTIL RELEASE FROM CATAPULT.	7	42	NOT REQUIRED DURING LAUNCH.	7	42	*NONE DURING RPV* ACCELERATION AND LAUNCH.	7	42	NONE.	7	42	*NOT REQUIRED. VEHICLE* LEAVES CATAPULT UNDER CONSTRAINT.	7	42	NOT REQUIRED UNTIL LIFTOFF SPEED.	6	36
36	NOT REQUIRED. CATAPULT HEADING IS HELD DURING RUN.	7	42	NOT REQUIRED DURING LAUNCH.	7	42	NONE DURING RPV LAUNCH PHASE.	7	42	NONE.	7	42	NOT REQUIRED. RPV LEAVES CATAPULT UNDER CONSTRAINT.	7	42	PROVIDED BY STEERING MECH ON DOLLY.	6	36
18	REQUIRED IMMEDIATELY AFTER LAUNCH.	6	36	NOT REQUIRED DURING *LAUNCH BUT AIR* CONTROL REQUIRED.	6	36	REQUIRED AFTER LAUNCH.	5	30	AFTER LAUNCH *GROUND CONTROL* REQUIRED.	5	30	REQUIRED BUT ONLY AFTER TAKE OFF SPEED IS ACHIEVED.	6	36	REQUIRED THROUGHOUT GROUND RUN.	2	12
24	MODERATE TO HIGH. DEPEND ON CATAPULT STROKE.	3	18	LOW "G" LEVELS.	4	24	VERY HIGH. MAY NEED REVISION OF WING LIFT CONCEPT.	1	6	HIGH. DEPENDS ON LENGTH OF CATAPULT AND T/W.	2	12	MODERATE FOR STOL CONFIGURATION.	4	24	LOW "G" LEVEL EXPERIENCED.	4	24
36	ABORT NOT POSSIBLE. ONCE ACTION STARTED VEHICLE *HAS TO GET AIRBORNE.*	2	12	ABORT NOT POSSIBLE. ONCE DROP ACTION *INITIATED.*	1	6	NONAVAILABLE AFTER MOTOR FIRES.	1	6	NONAVAILABLE AFTER MOTOR FIRES.	1	6	NORMALLY NOT POSSIBLE ONCE ACTION IS STARTED.	2	12	VERY GOOD. CAN ABORT AT ANY TIME.	6	36
50	AS PER COLUMN 1 LANDING GEAR WEIGHS 150 LBS.	4	40	AVERAGE. LARGE WEIGHT OF RECOVERY PARACHUTE.	4	40	AVERAGE. GEAR AND SKIDS ARE SIMILAR IN EFFECT.	4	40	NO GEAR AND NO PARACHUTE GIVES GOOD △ RANGE.	7	70	AS PER COL. 1 LANDING GEAR WEIGHT IS 150 LBS–VOL–8 CU FT.	4	40	GOOD. WITH NO GEAR AND ACLS WEIGHT SHOULD BE LOW.	6	60
18	VERY LOW. TOW BARS AND JEEPS TO TOW RPVs REQUIRED.	6	36	COMPLEX CRANES, LIFT DOLLIES, TRANSPORT DOLLIES, TRACTORS, ETC.	2	12	REQUIRED. TOW TRUCKS, DOLLIES, AND CRANES ARE REQUIRED.	2	12	COMPLEX CRANES. LIFT DOLLIES. TRANSP. FLAT BEDS, ETC.	1	6	VERY LOW. TOW JEEPS AND TOW BARS VEHICLE ON WHEELS.	6	36	POOR. REQUIRES CRANES, STATIC DOLLIES.	3	18
12	NIL. SHUTTLE RETURN IS OR CAN BE AUTOMATIC.	6	36	NONE.	7	42	NONE EXCEPT RECYCLE OF MOTOR.	5	30	*NONE EXCEPT* RECYCLE OF MOTOR.	5	30	*NIL. SHUTTLE IS* RETURNED TO TAKE OFF POSITION AUTOMATICALLY.	6	36	DOLLY NEEDS TO BE RECOVERED HIGH DAMAGE POTENT.	2	12
9	POSSIBLE DAMAGE CAN RESULT FROM FAILED CABLES WHIPS.	4	12	NONE.	7	21	VERY SERIOUS. HEAT AND SMOKE ARE HIGH DURING LAUNCH.	1	3	SERIOUS. HEAT SMOKE AND DEBRIS PRESENT.	2	6	DAMAGE TO EQUIPMENT CAN RESULT FROM CABLE WHIPS.	4	12	NEGLIGIBLE EXCEPT HARD POINTS INTERFACE.	4	12
18	VERY GOOD. SOME EXTRA CARE NEEDED BECAUSE OF CATAPULT.	5	30	NONE. ONLY VIA *DIRECT AND REMOTE* CONTROL.	1	6	NOT TOO GOOD. RPV *IS WAY ABOVE* NORMAL WALKING LEVEL.	2	12	NOT TOO GOOD. RPV *IS ABOVE NORMAL* WALKING LEVEL.	2	12	VERY GOOD. EASY *ACCESS BUT CARE* NEEDED BECAUSE OF CATAPULT.	5	30	FAIR TO GOOD. DOLLY BLOCKS ACCESS.	4	24
40	AVERAGE. CATAPULTS EQUIPMENT REQUIRES SPECIAL CARE (WHIPS).	3	30	LESS THAN AVERAGE. RPV REPRESENT HAZARD TO CARRIER AIRCRAFT.	3	30	BELOW AVERAGE. HEAT AND ROCKET FUMES ARE PRESENT.	2	20	BELOW AVERAGE. HEAT, ROCKET FUMES ARE PRESENT.	2	20	AVERAGE. CATAPULTS REQUIRE SPECIAL CARE IN HANDLING.	3	30	VERY GOOD. NO FUMES AND DEBRIS DURING L.	6	60
18	EXCESSIVE. CATAPULT AND VEHICLE HANDLING PEOPLE ARE REQUIRED.	2	12	EXCESSIVE. INCLUDES PERSONNEL MANNING *AIRCRAFT AND RPVs.*	2	12	AVERAGE. 3 MEN ON VEHICLE–2 MEN IN CONTROL STATION.	5	30	EXCESSIVE. CATAPULT AND RPV HANDLING MUST BE DONE.	2	12	EXCESSIVE. AT LEAST 9 TO 11 PEOPLE ARE REQUIRED TO MAINTAIN.	3	18	MORE THAN AVERAGE.	3	18
18	AVERAGE TO HIGH. 6 X (3) 3 X (5) 1 X (7).	2	12	HIGH SKILL LEVEL REQUIRED. PREDOMINANTLY TO SERVICE AIRCRAFT RPV INTER.	2	12	HIGH SKILLS REQUIRED. 3 X (5) 2 X (7).	2	12	AVERAGE TO HIGH 4 X (3) 3 X (5) 2 X (7).	2	12	AVERAGE TO HIGH 6 X (3) 3 X (5) 2 X (7) APPX.	2	12	HIGH SKILL LEVEL REQUIRED TO STEER DOLLY.	2	12
60	VERY GOOD. CAN OPERATE IN ANY WEATHER.	6	60	VERY GOOD. CAN DEPLOY RPV IN ALL WEATHER.	6	60	EXCELLENT. CAN LAUNCH IN ANY WEATHER.	7	70	EXCELLENT. CAN LAUNCH IN ANY WEATHER.	7	70	VERY GOOD. CAN OPERATE IN ANY WEATHER DAY/NIGHT.	6	60	STEERING MECH AFFECTED BY MUD AND SNOW.	4	40
30	HIGH LEVEL OF SURVIVALS EXPECTED FROM CAT. LAUNCH.	6	60	VERY GOOD.	6	60	AVERAGE TO HIGH PROVIDED BOTH VEHICLE AND RPV MEET STANDARDS.	4	40	*BETTER THAN* AVERAGE. VEHICLE HAS LONGER RUN (LESS "G").	5	50	*EXCELLENT TO HIGH* STOL CONFIGURATION HELPS SURVIVABILITY.	7	70	*GOOD.* CRITICAL POINT IF LEAVING DOLLY.	5	50
18	MODERATE REQUIRE NEARLY SAME DISTANCE AS PER STOL.	3	18	LONG. AIRFIELD RUNWAY LENGTH FOR C-130 DEPLOYMENT IS LARGE.	2	12	AT HIGH "G" LEVELS NEGLIGIBLE TOTAL LENGTH OF LAUNCH RAIL (2 TRUCKS) IS 107 FT.	6	36	100–150 FT NO PROBLEM WITH REAL ESTATE.	6	36	SMALL TO MODERATE STOL CONFIGURATION HELPS TO REDUCE L. DIST.	5	30	LONG. DOLLY CREATES MORE DRAG DURING RUN.	2	12
36	*PREPARED MATTING* PREFERRED.	4	24	RUNWAY REQUIRED OR WELL PREPARED SURFACE.	3	18	ANY LEVEL GROUND.	7	42	PREPARED SURFACE REQUIRED.	5	30	PREPARED FIELD MATTING PREFERRED.	4	24	PREPARED *FIELD REQUIRED* MATTING.	5	30
18	CATAPULT AND BRIDDLES WITH SUPPORT EQUIPMENT REQUIRED.	3	18	AIRCRAFT PYLONS HAVE TO BE BEEFED UP TO TAKE 8000 LBS RPV.	2	12	NONE EXCEPT FOR RATO BOTTLES.	7	42	DEPENDS ON PROPULSIVE TYPE IMPULSE RATO OR STEAM.	7	42	CATAPULT ITSELF WITH BRIDLES AND SHUTTLES.	4	24	REQUIRED. DOLLY STEERING LOCALIZER REQUIRED.	3	18
20	VULNERABLE IF CATAPULT DAMAGED OPERATIONS WILL STOP.	2	20	VERY HIGH IN EUROPEAN SCENARIO.	2	20	AVERAGE WITH GOOD WARNING OF ATTACK.	4	40	AVERAGE TO LOW FOR RATO. HIGH *FOR STEAM.*	4	40	VULNERABLE IF CATAPULT HIT–OPERATIONS STOP.	2	20	VULNERABLE DISPERSAL MORE COMPLEX.	3	30
683 3.69	Σ = 742 FOM = 4.01			Σ = 693 FOM = 3.74			Σ = 771 FOM = 4.16			Σ = 706 FOM = 3.81			Σ = 788 FOM = 4.25			[illegible]		

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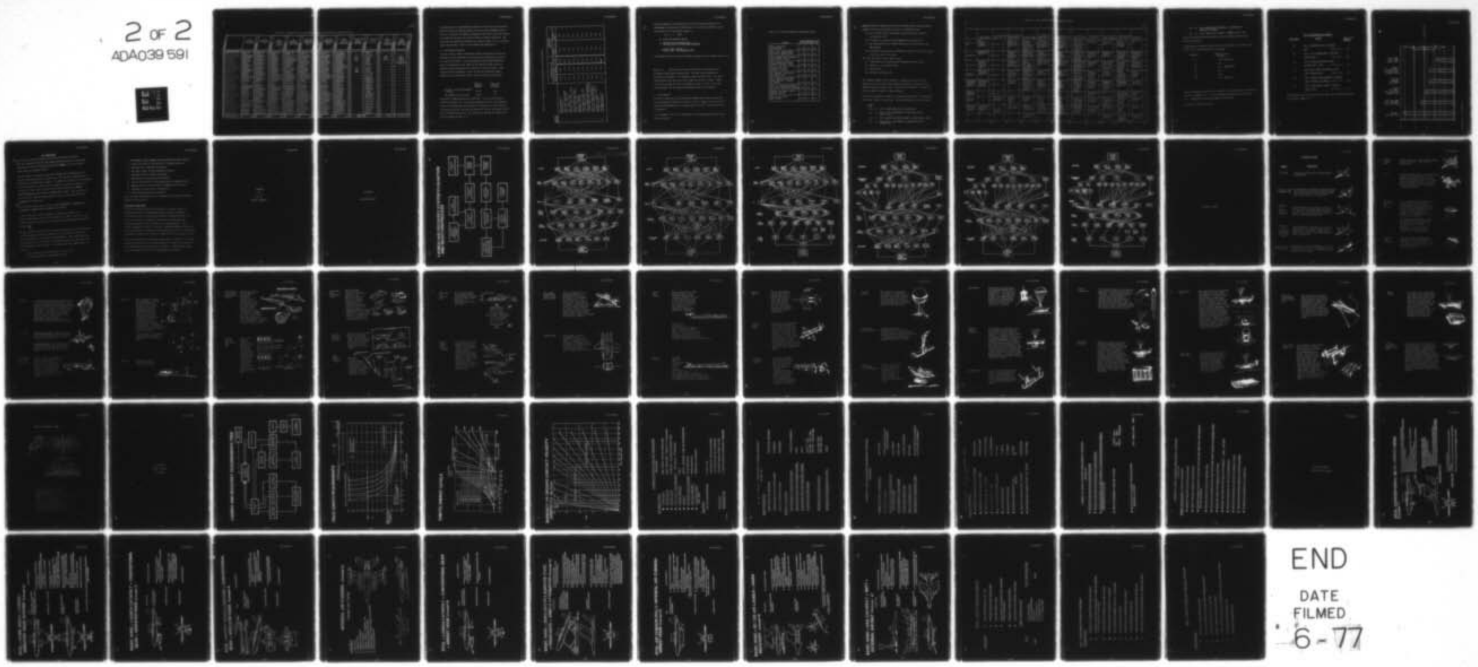

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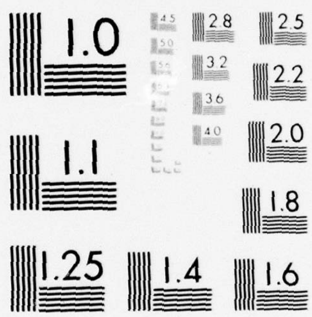

MICROCOPY RESOLUTION TEST CHART
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Table 6.2-2. The Operational Assessment (Recov

WEIGHTING FACTORS	SYSTEM RECOVERY DESCRIPTOR	1: STOL + CONVENTIONAL GEAR + ARRESTER GEAR	BASIC RATING	WEIGHTED RATING	2: ZEL + TVC + DUAL MODE PARACHUTE + AIR BAG	BASIC RATING	WEIGHTED RATING	3: STOL + WHEELED DOLLY + ARRESTER GEAR + SKIDS (WITH AIR BAGS)	BASIC RATING	WEIGHTED RATING	4: STOL + AIR CUSHION DOLLY + ARRESTER GEAR + INTEGRAL AIR CUSHION	BASIC RATING	WEIGHTED RATING	5: CATAPULT RUNWAY + CONVENTIONAL GEAR + ARRESTER GEAR (NO STOL)	BASIC RA[TING]
3	APPROACH ACCURACY REQMT (10 NMI)	AVERAGE. USING MICROWAVE LANDING SYSTEM.	4	12	AVERAGE. USING GROUND CONTROL STATION.	6	18	AVERAGE. USING MICROWAVE LANDING SYSTEM.	4	12	AVERAGE. USE OF MICROWAVE LANDING SYSTEM.	4	12	AVERAGE. USING MICROWAVE LANDING SYSTEM.	4
10	ACCURACY REQMTS ON FINALS (2 NMI)	HIGH ACCURACY REQUIRED. TO OBTAIN GROUND CONTACT AND WIRE ARRESTMENT.	3	30	MODERATE. ALTITUDE AND POSITION FOR PARA DEPLOYMENT.	6	60	HIGH ACCURACY REQUIRED FOR WIRE ARREST.	3	30	HIGH ACCURACY REQUIRED FOR WIRE ARREST.	3	30	VERY HIGH ACCURACY. REQUIRED BECAUSE OF HIGH APPROACH SPEED.	2
6	RECOVERY SURFACE REQD	PREPARED. MATTING OR FIRM EVEN GROUND IS SATISFACTORY.	5	30	PREPARED.–FOR ACCESSIBILITY OF RECOVERY EQUIPMENT.	5	30	PREPARED. MATTING OR FIRM GROUND IS SATISFACTORY.	5	30	PREPARED. MATTING–FIRM OR SOFT GROUND. CBR–2 AND UP ALSO WATER (POSSIBLY).	6	36	PREFERABLY RUNWAY–BECAUSE OF HIGH LAND SPEED.	3
6	DRIFT TOLERANCE AT IMPACT	VERY GOOD. CAN ACCEPT 30 NMI CROSS WIND AT IMPACT.	6	36	POOR. DAMAGE RESULTS FROM DRIFTS AND DISLOCATION.	2	12	VERY GOOD. CAN ACCEPT 30 NMI X WIND AT IMPACT.	6	36	VERY GOOD. ARRESTER GEAR CAN ACCEPT 30 NMI X WIND.	6	36	POOR TO FAIR. DRIFT ANGLE MAY BE SMALL BUT DRIFT IMPACT IS BAD.	3
6	ATTITUDE CONTROL TOLERANCE	LOW. MUST MAKE CONTACT WITH GROUND EVENLY ON WHEELS.	3	18	POOR. MUST NOT IMPACT WING OR TAIL FIRST.	2	12	LOW. MUST MAKE EVEN CONTACT WITH SKIDS.	3	18	LOW. MUST BE AT RIGHT ATTITUDE FOR IMPACT.	3	18	LOW. MUST MAKE CORRECT ATTITUDE CONTACT.	3
10	INTERNAL IMPACT ATTENUATORS REQMTS	NONE. ALL IMPACT ABSORBTION IS IN THE GEAR AND ARREST GEAR.	6	60	REQUIRED. INTERNAL AIR BAG PROVIDED FOR RECOVERY.	2	20	NONE. ALL ENERGY ABSORPTION IS IN THE SKID SYSTEM.	6	60	NONE. AIR CUSHION IS AN IMPACT ATTENUATOR.	6	60	NONE. ALL IMPACT ABSORBTION WILL BE IN THE GEAR SYSTEM.	6
10	DISPERSION RADIUS ON IMPACT	VERY GOOD. PREDICTABLE DISPERSION AT IMPACT WITHIN CONSTRAINTS.	6	60	POOR. CANNOT CONTROL DISPERSION OF VEHICLES.	2	20	VERY GOOD. ARRESTMENT LOCATION IS PREDICTABLE.	5	60	VERY GOOD. USING ARRESTER GEAR EQUIPMENT.	6	60	VERY GOOD. ARRESTMENT LOCATION IS PREDICTABLE.	6
3	DECELERATION LEVELS "G"	ACCEPTABLY LOW. ARRESTER GEAR LANDING TYPICAL.	6	18	HIGH ON PARACHUTE OPENING MAY RESULT IN VEHICLE DAMAGE.	3	9	ACCEPTABLY LOW. COMPATIBLE WITH TYPICAL ARRESTER GEAR.	6	18	ACCEPTABLY LOW COMPATIBLE WITH TYPICAL ARRESTER GEAR.	6	18	HIGH TO MODERATE. HIGH SPEED OF TOUCH DOWN GIVES HIGHER "G".	3
6	MOBILITY OF SET UP AND WIND DOWN	GOOD TO FAIR. DEPENDING ON USE OF MATTING AND TYPE OF ARRESTER GEAR.	4	24	EXCELLENT. NO EQUIPMENT IS ASSIGNED TO RECOVERY.	7	42	POOR. ARRESTER GEAR + TRANSFER OF VEHICLES TO TRANSPORTERS.	3	18	POOR. RPV CANNOT BE MOVED ON GROUND CUSHION ONLY ON TRAILER.	2	12	GOOD TO FAIR. DEPENDING ON USE OF MATTING AND TYPE OF ARREST GEAR.	4
10	SPECIAL EQUIPMENT REQD	REQUIRED. ARRESTER GEAR + MLS APPR. TYPE. 2 PER LAUNCH SITE.	3	30	NONE EXCEPT GROUND CONTROL STATION.	7	70	REQUIRED ARRESTER GEAR + MLS + WHEELS ADDED TO SKIDS.	1	10	REQUIRED. DOLLIES LIFT CRANES, STATIC DOLLIES, ETC.	1	10	ARRESTER GEAR + MLS–2 PER LANDING SITE.	3
6	MANPOWER REQD AND SKILL	AVERAGE. 6 X (3), 2 X (5) 1 X (7).	4	24	AVERAGE 7 X (3) 2 X (5) 1 X (7).	3	18	FAIR. 7 X (3) 2 X (5) A6 1 X (7).	3	18	FAIR TO MODERATE. 7 X (3) 2 X (5) 1 X (7).	3	18	AVERAGE. 6 X (3) 2 X (5) 1 X (7).	4
10	EXPECTED DAMAGE ON RECOVERY	VERY LOW. GOOD APPROACH AND ACCURACY OF GROUND CONTACT GIVE LOW DAMAGE.	6	60	MODERATE DAMAGE EXPECTED ON AVERAGE.	4	40	LOW. SKID ARRESTMENT SHOULD GIVE NO DAMAGE.	6	60	LOW TO MODERATE. DEPENDS ON AIRCRAFT CLEARANCE AND STIFFNESS.	4	40	LOW TO MODERATE. BECAUSE OF HIGH IMPACT SPEEDS.	4
6	GROUND HANDLING EQUIPMENT	VERY LOW. SAME AS USED FOR TAKE-OFF TOW BAR JEEPS.	6	36	OVERLAND TRUCKS. FLAT BEDS AND CRANES NEEDED FOR RECOVERY.	2	12	NUMEROUS CRANES. TOW TRUCKS. TRANSPORTERS. TOWING EQUIPMENT.	3	18	NUMEROUS CRANES. TOW TRUCKS TRANSPORTERS, DOLLY MOVERS.	3	18	VERY LOW. TOW BAR AND JEEPS.	6
10	MISSION RANGE EFFECTS	AS PER TAKE-OFF WEIGHT OF GEAR 150 LBS VOLUME 8.3 CU. FT.	4	40	POOR. WEIGHT OF PARACHUTE AND AIR BAGS 800 LBS.	2	20	BETTER THAN AVERAGE. SKIDS WEIGH LESS THAN WHEELS.	5	50	GOOD. WEIGHT AND VOLUME OF INTERNAL EQUIPMENT IS LOW.	5	50	GEAR WEIGHT MAY BE BEEFED UP BECAUSE OF HIGH SPEED.	3
10	RELIABILITY OF RECOVERY EQUIPMENT (GROUND)	VERY GOOD. VERY FEW PROBLEMS EXPECTED.	6	60	NOT INVOLVED. INTERNAL RECOVERY ONLY–GOOD BENEFIT.	7	70	VERY GOOD. NO PROBLEMS WITH ARRESTER GEAR.	6	60	GOOD. BUT DEPENDS ON ACLS INTEGRITY AND STRENGTH.	5	50	VERY GOOD TO GOOD. BUT MORE PROBLEMS EXPECTED WITH ARREST GEAR.	5
10	ALL WEATHER COMPATIBILITY	SATISFIED WITH LMS EQUIPMENT.	6	60	SATISFIED. CAN RECOVER IN ALL WEATHER.	6	60	SATISFIED WITH MLS EQUIPMENT CAN RECOVER ALL WEATHER.	6	60	SATISFIED WITH MLS EQUIPMENT.	6	60	SATISFIED WITH MLS AND ARRESTER GEAR–MORE COMPLICATIONS.	5
10	SUSTAINED RECOVERY RATE	VERY GOOD. AT LEAST 12 PER HOUR PER LAUNCH CHANNEL.	6	60	GOOD. VEHICLES DO NOT DEPEND ON QUEING, BUT DISPERSAL POOR.	6	60	VERY GOOD. AT LEAST 12 PER HOUR PER CHANNEL.	6	60	FAIR. SOME PROBLEMS EXPECTED WITH CLEARANCE OF RECOVERY AREA.	3	30	VERY GOOD TO GOOD. HIGHER SPEEDS MAY CAUSE PROBLEMS.	5
6	GROUND CONTROL REQMTS (CDRS)	REQUIRED. GROUND CONTROL STATION FOR APPROACH SAME AS TAKE OFF.	3	18	REQUIRED SAME AS TAKE OFF.	3	18	REQUIRED. SAME AS COLUMN 1.	3	18	REQUIRED GROUND CONTROL STATION TO MONITOR APPROACH.	3	18	REQUIRED SAME AS COLUMN 1.	3
6	REUSABILITY OF RECOVERY EQUIPMENT	VERY GOOD. SYSTEM CAN SUSTAIN CONSTANT OPERATION.	6	36	PROBABLY NONE. PARACHUTES GET DAMAGED TOO MUCH.	1	6	VERY GOOD. SYSTEM CAN SUSTAIN MULTIPLE RECOVERY.	6	36	PROBABLY POOR. ABRASIONS AND DAMAGE TO ACLS POSSIBLE.	2	12	VERY GOOD. SYSTEM CAN SUSTAIN CONSTANT OPERATION.	6
10	CONTRIBUTION TO TURNAROUND	VERY LOW. RECOVERY OPERATION IS FAST AFTER ARRESTMENT.	6	60	VERY HIGH. IT TAKES TOO LONG TO RECOVER VEHICLE AND DELIVER TO T. A. PAD.	1	10	HIGH. TOWING ON SKIDS LESS EFFICIENT THAN ON WHEELS.	2	20	HIGH. REPACKING AND RECHECKING OF ACLS ON AIRCRAFT LENGTHY.	2	20	VERY LOW. RECOVERY IS FAST AFTER ARRESTMENT.	5
10	VULNERABILITY (ENEMY ACTION)	VEHICLES CAN BE DISPERSED. ARRESTER GEAR IS VULNERABLE.	4	40	NOT VULNERABLE. ONLY GROUND CONTROL ON GROUND VULNERABLE.	6	60	MORE THAN AVERAGE. RPVs ARE LESS MANEUVERABLE ON GROUND ON DOLLIES.	3	30	VULNERABLE. PENETRATION OF AIR CUSHION BAGS CRITICAL.	2	20	ARRESTER GEAR ONLY. VEHICLES CAN BE DISPERSED.	4
Σ OF WEIGHTED FACTORS = 164		Σ = 812 FOM = 4.95			Σ = 667 FOM = 4.06			Σ = 722 FOM = 4.40			Σ = 628 FOM = 3.82			Σ = [illegible] FOM = 4.	

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…nal Assessment (Recovery) of Finalist Systems

…LY + … + …ION: BASIC RATING	WEIGHTED RATING	CATAPULT RUNWAY + CONVENTIONAL GEAR + ARRESTER GEAR (NO STOL)	BASIC RATING	WEIGHTED RATING	AIR LAUNCH BY DC-130H RECOVERY BY MARS (HH-53) HELICOPTER	BASIC RATING	WEIGHTED RATING	HYBRID TRUCK LAUNCHER PLUS STOL + ARRESTER GEAR + SKIDS OR WHEELS	BASIC RATING	WEIGHTED RATING	CATAPULT RAIL (RATO) + MITT + EXTERNAL AIR MAT	BASIC RATING	WEIGHTED RATING	CATAPULT (RUNWAY-SATS) + STOL + CONVENTIONAL GEAR + ARRESTER GEAR	BASIC RATING	WEIGHTED RATING	STOL + WHEELED DOLLY (STEERABLE) + ARRESTER GEAR + INTEGRAL AIR CUSHION	BASIC RATING	WEIGHTED RATING
		5			6			7			8			9			10		
4	12	AVERAGE. USING MICROWAVE LANDING SYSTEM.	4	12	LOW TO AVERAGE. VISUAL ALIGNMENT IS ONLY NEEDED FOR MARS.	6	18				AVERAGE. USE GROUND CONTROL STATION.	6	18						
3	30	VERY HIGH ACCURACY. REQUIRED BECAUSE OF HIGH APPROACH SPEED.	2	20	VERY HIGH. FINAL ALIGNMENT REQUIRES PRECISION BY HELICOPTER.	3	30	AS PER			HIGH. MUST ENGAGE CENTER OF MITT.	3	30	AS PER			AS PER		
6	36	PREFERABLY RUN-WAY–BECAUSE OF HIGH LAND SPEED.	3	18	NONE IN THE AIR. ON LOWERING TO GROUND-PREPARED SURFACE.	6	36	COLUMN 1 (WHEELS)			ANY SUITABLE PREPARED SURFACE.	6	36	COLUMN 1 WHEELS-4.95			COLUMN 4 ARRESTED GEAR		
6	36	POOR TO FAIR. DRIFT ANGLE MAY BE SMALL BUT DRIFT IMPACT IS BAD.	3	18	NONE IN AIR. ON GROUND LOWERING–GOOD TOLERANCE.	5	30				HIGH DRIFT TOLERANCE EXPECTED.	6	36				PLUS INTEGRAL AIR CUSHION		
3	18	LOW. MUST MAKE CORRECT ATTITUDE CONTACT.	3	18	NOT REQUIRED ON ARRESTMENT–RPV MUST BE LEVEL ON LOWERING.	6	36				HIGH TOLERANCE EXPECTED.	6	36				FOM = 3.82		
6	60	NONE. ALL IMPACT ABSORBTION WILL BE IN THE GEAR SYSTEM.	6	60	NONE REQUIRED. "G" IS HIGH ON ARRESTMENT AND LOW ON LOWERING.	6	60	AS PER			NO INTERNAL ATTENUATORS.	7	70						
6	60	VERY GOOD. ARREST-MENT LOCATION IS PREDICTABLE.	6	60	NOT APPLICABLE. ON LOWERING ACCURACY IS EXCELLENT.	7	70	COLUMN 3 (SKIDS)			VERY GOOD. AREA CLEARLY DEFINED.	6	60						
6	18	HIGH TO MODERATE. HIGH SPEED OF TOUCH-DOWN GIVES HIGHER "G."	3	9	HIGH ON ARRESTMENT. 3–5 "G's"–LOW ON LOWERING–1 "G."	6	18				LOW "G" EXPECTED IN MITT RECOVERY.	6	18						
2	12	GOOD TO FAIR. DEPENDING ON USE OF MATTING AND TYPE OF ARREST GEAR.	4	24	HELICOPTERS ARE BETTER THAN AIRCRAFT TO CHANGE LOCATION.	3	18				POOR. THE SET-UP AND WIND DOWN IS COMPLEX.	1	6						
1	10	ARRESTER GEAR + MLS–2 PER LANDING SITE.	3	30	MARS EQUIPMENT REQUIRED IN HELI-COPTER–EXPENSIVE.	3	30				LASER SEEKERS AND DESIGNATORS AND ALSO AIR MAT.	2	20						
3	18	AVERAGE. 6 X (3) 2 X (5) 1 X (7).	4	24	HIGH SKILL LEVEL REQUIRED 3 X (3) 2 X (5) 2 X (7).	2	12				HIGH LEVELS OF MAN-POWER ROD–20 X (3) 5 X (5) 3 X (7).	1	6						
4	40	LOW TO MODERATE. BECAUSE OF HIGH IMPACT SPEEDS.	4	40	GENERALLY LIGHT DAMAGE IF MARS WORKS.	6	60				LIGHT DAMAGE OR NO DAMAGE ON RECOVERY.	6	60						
3	18	VERY LOW. TOW BAR AND JEEPS.	6	36	NUMEROUS. CRANES TOW TRUCKS, DOLLIES, FLAT BEDS, ETC.	2	12				NUMEROUS. CRANES TOW TRUCKS, DOLLIES, FLAT BEDS, ETC.	1	6						
5	50	GEAR WEIGHT MAY BE BEEFED UP BECAUSE OF HIGH SPEED.	3	30	AVERAGE. WEIGHT OF RECOVERY PARA-CHUTE IS 350 LBS.	4	40				GOOD. ONLY PLAIN VEHICLE – NO GEAR OR PARACHUTE.	7	70						
5	50	VERY GOOD TO GOOD. BUT MORE PROBLEMS EXPECTED WITH ARREST GEAR.	5	50	NOT APPLICABLE EXCEPT FOR HELI-COPTER SERVICING.	4	40				FAIR TO GOOD. MITT BALLOONS ARE SUBJECT TO DAMAGE.	3	30						
6	60	SATISFIED WITH MLS AND ARRESTER GEAR–MORE COMPLICATIONS.	5	50	NOT COMPATIBLE ONLY VFR RECOVERY IS POSSIBLE.	1	10				NOT TOO GOOD. MUST HAVE GOOD VISIBILITY FOR ARREST.	2	20						
3	30	VERY GOOD TO GOOD. HIGHER SPEEDS MAY CAUSE PROBLEMS.	5	50	VERY LOW. DEPENDS ON NUMBER OF RECOVERY HELICOPTERS.	1	10				LOW. SYSTEM HAS TO BE RESET AFTER RECOVERY.	2	20						
3	18	REQUIRED. SAME AS COLUMN 1.	3	18	REQUIRED. HELICOPTER MUST KNOW DRONE POSITION FOR RECOVERY.	3	18				REQUIRES GROUND CONTROL STATION.	3	18						
2	12	VERY GOOD. SYSTEM CAN SUSTAIN CONSTANT OPERATION.	6	36	POOR. PARACHUTES ARE JETTISONED AND ARE NOT REUSED.	1	6				EXPECTED HIGH. BALLOONS CAN BE PATCHED UP IF DAMAGED.	4	24						
2	20	VERY LOW. RECOVERY IS FAST AFTER ARRESTMENT.	5	50	LOW TO MODERATE. RPVs CAN BE DELIVERED TO TURNAROUND AREAS.	4	40				HIGH. REMOVAL AND RETRIEVAL OF RPV IS SLOW.	2	20						
2	20	ARRESTER GEAR ONLY. VEHICLES CAN BE DISPERSED.	4	40	VERY HIGH. IN EUROPEAN SCENARIO.	1	10				VERY HIGH. IN EUROPEAN SCENARIO.	1	10						
Σ = 628 … = 3.82		Σ = 693 FOM = 4.22			Σ = 604 FOM = 3.68			FOM WHEELS = 4.95 FOM SKIDS = 4.40			Σ = 614 FOM = 3.74			FOM WHEELS = 4.95			FOM INTEGRAL A.C. = 3.82		

The descriptors are self-explanatory except for the skill levels descriptor where the figure in brackets denotes the service skill designation and in front of the bracket the number of personnel at the skill level that follows. The evaluation concerns itself with the ARPV in tactical operations. The results of the operational assessment are shown in Table 6.2-3 as a separate launch and recovery, as well as the combined L&R FOM quantity.

6.3 COST/BENEFITS ANALYSIS

In order to have a basis of comparison between the numerous systems that remained as viable candidates, two existing drone systems were selected as a baseline reference - one ground-launched system (AQM-34V/BGM 34C) which is represented in this report by the ZEL(TVC) system and an air-launched system represented by DC-130E(or H) with Mars Recovery. Both systems have been evaluated in terms of cost and operational aspects (benefits) in the preceding section. The basic data are given below:

	L.C. COST PER SORTIE $	OPERATIONAL F.O.M.
ZEL(TVC) + DUAL MODE PARACHUTE + AIR BAG	27,853	4.23
AIR LAUNCH BY DC-130 + MARS	36,260	3.71

To provide a compatible basis for comparison (the cost data being in different dimensions ($) than the non-dimensional F.O.M.'s) the modified cost of all systems under this analysis was normalized to these two basic references by directly dividing the system cost into the referenced ZEL(TVC) and DC-130/MARS System Costs. The results thus obtained are shown in the last two columns of Table 6.2-3.

Table 6.2-3 Summary of Operational Assessments & Cost Normalization

COMBINED RANK NO.		OPERATIONAL F.O.M.			NORMALIZED COST F.O.M.	
		F.O.M. LAUNCH	F.O.M. RECOVERY	F.O.M. L & R	ZEL(TVC) + PARA + AIR B.	DC-130 + MARS
1	STOL + CONV GEAR + ARRESTER GEAR	5.00	4.95	4.975	2.06	2.68
2	STOL + SATS CATAPULT(MOD) CONV. GEAR + ARR. GEAR	4.25	4.95	4.60	1.55	2.02
3	STOL + HYBRID TRUCK LAUNCHER + ARR. GEAR + SKIDS	4.16	4.40	4.28	1.29	1.68
4	STOL + WHEELED DOLLY(WIRE GUIDED) + ARR GEAR + SKIDS	4.09	4.40	4.245	1.79	2.27
5	ZEL(TVC), DUAL MODE PARACHUTE + AIR BAG	4.40	4.06	4.23	1.00	1.30
6	SATS CATAPULT + CONV. GEAR + ARR. GEAR (NO STOL)	4.01	4.22	4.115	1.73	2.25
7	STOL + WHEELED DOLLY(STEERABLE) + ARREST GEAR + INT. AIR CUSHION	3.94	3.82	3.88	1.95	2.53
8	STOL + AIR CUSH DOLLY(DROPP) + ARR GEAR + INTEGR AIR CUSHION	3.69	3.82	3.75	1.75	2.28
9	CATAPULT RAIL(RATO) + MITT + EXTERNAL AIR MAT	3.81	3.74	3.775	1.29	1.68
10	AIR LAUNCH BY DC-130 H HELICOPTER RECOVERY	3.74	3.68	3.71	0.76	1.00

Once the respective cost and operational F.O.M.'s have been obtained, the methodology of obtaining the relative merit of the total cost/benefit in comparison with one of the present systems is:

$$F_R = K \quad L \qquad \text{where}$$

F_R = Fixed Cost/Benefits Rating

$$K = \frac{\text{Cost per Sortie DC-130(or ZEL)}}{\text{Cost per Sortie - System Under Assessment}}$$

$$L = \frac{\text{F.O.M. (L\&R) - System}}{\text{F.O.M. (L\&R) - DC-130/MARS(or ZEL)}}$$

This approach yields the final Cost/Benefits figures which are shown in Table 6.3-1.

Table 6.3-1 shows the final results derived from the operational/cost assessments normalization defined above. The final rating column under ZEL gives the standing of all remaining systems relative to ZEL. The second column presents the same results with respect to DC 130 air launch. Column 3 gives the averages of these two standings in order to arrive at one final selection number for the combined Cost/Benefits part of the analysis.

6.4 RISK ANALYSIS

In order to assess the risk associated with launch and recovery systems that were discussed and evaluated in Sections 6.2 and 6.3 above, it was necessary to define the terminology and the procedure that was used in connection with the risk analysis.

For the purpose of this L & R trade study, the terminology and procedures used were as follows:

Table 6.3-1 Final Cost/Benefits Assessments Values

SYSTEM	FINAL RATING ZEL	FINAL RATING DC-130	AVERAGE OF TWO	
STOL + CONV GEAR + ARRESTER GEAR	2.42	3.59	3.00	1
STOL + SATS CATAPULT(MOD) + CONV GEAR + ARRESTER GEAR	1.68	2.50	2.09	5
STOL + HYBRID TRUCK LAUNCHER + ARRESTER GEAR + SKIDS	1.30	1.93	1.61	7
STOL + WHEELED DOLLY(WIRE GUIDED) + ARR GEAR + SKIDS	1.795	2.59	2.19	3
ZEL(TVC) DUAL MODE PARACHUTE + AIR BAG	1.0	1.48	1.24	9
SATS CATAPULT + CONV GEAR + ARR GEAR(NO STOL)	1.68	2.49	2.08	6
STOL + WHEELED DOLLY(STEER-ABLE)+ ARR GEAR + INTEGRAL AIR CUSHION	1.78	2.64	2.20	2
STOL + AIR CUSH DOLLY(DROPP) + ARR GEAR + INTEGRAL AIR CUSHION	1.59	2.63	2.11	4
CATAPULT RAIL(RATO) + MITT + EXTERNAL AIR MAT	1.15	1.70	1.42	8
DC-130 - AIR LAUNCH MARS RECOVERY	0.66	1.0	0.83	10

Risk was defined as probability that both the launch and the recovery method proposed in the list of finalists in the L & R systems will not

(a) meet the ARPV mission requirements (high sortie rates, mobility, survivability, etc)

(b) be capable of satisfactory development within the ARPV IOC

(c) meet the specified cost limits, resulting in cost overruns for the ARPV program

(d) be amenable to generation of technical alternatives, in lieu, to satisfy either (a), (b), or (c) above

The other descriptors in this analysis were:

(1) classification of a system within technology state of the art

(2) definition of the problem areas

(3) uncertainties

(4) actions to alleviate risk.

The treatment adopted in this study was a formulation of a matrix which addresses all of the above considerations and assigned a rating scale and weighting factors to each of them. They were then evaluated in a simplified P.O.E.D. method to generate a Figure of Merit.

The matrix is presented in Table 6.4-1, "Risk Analysis Matrix". The shortened list of the results is shown below. The high FOM indicates low risk rating.

F.O.M.		
5.52	#1	STOL + CONVENTIONAL GEAR + ARRESTER GEAR
5.32	#2	STOL + SATS CATAPULT(MOD) + CONVENTIONAL GEAR + ARRESTER GEAR
4.32	#3	STOL + WHEELED DOLLY(WIRE GUIDED) + ARRESTER GEAR + SKIDS
4.05	#4	BASIC WING + SATS CATAPULT + CONVENTIONAL GEAR + ARRESTER GEAR

Table 6.4-1 Risk Analysis Matri

		STOL + CONV GEAR + ARRESTER GEAR		STOL + STATS CATAPULT + CONV GEAR + ARR GEAR		STOL + HYBRID TRUCK LAUNCHER + ARRESTER GEAR + SKIDS		ZEL(TVC) DUAL MODE PARACHUTE + AIR BAG		STOL + WHEELED DOLLY (WIRE GUIDED) + ARR GEAR + SKIDS	
10	STATE OF THE ART	MANY WORLDWIDE OPERATIONAL SYSTEMS IN EVERYDAY USE	7/70	← DITTO	7/70	ONLY 3 SIMILAR SYSTEMS IN EXISTANCE BUT VEHICLE WEIGHT IS 1/3-1/10 OF ARPV	3/30	BOTH SYSTEMS ARE UNDER DEVELOPMENT IN RPV FIELD BGM-34 SERIES ZEL & AIR BAGS TECHNOLOGY IS CURRENT	5/50	WHEELED DOLLY IS A STATE OF THE ART IN DIFFERENT APPLICATIONS. WIRE GUIDANCE OF WHEEL DOLLY IS NOT.	5/50
10	PROBLEM AREAS	CONTRIBUTION TO VEHICLE WEIGHT AND SIZE	3/30	← DITTO	3/30	SIZE OF TRUCK-LAUNCHERS - HANDLING OF REUSABLE RATO ENVIRONMENTAL EFFECTS.	3/30	AIRBAG PACKAGING FOR FLIGHT. PARACHUTE DISPERSION. ROCKET DISPOSAL AFTER LAUNCH.	3/30	INTEGRITY OF GUIDANCE & REPEATABILITY OF THE SYSTEM-RECOVERY OF DOLLY AFTER LAUNCH	4/40
6	UNCERTAINTIES	POSSIBLY MLS AUTOLAND ACCURACY FOR TOUCH DOWN - (DIRECT LIFT CONTROL)	6/36	← DITTO	6/36	ALIGNMENT OF 2 TRUCKS;LIFTING OF ARPV ON RAILS;ARRESTMENT OF SHUTTLE	3/18	DEGREE OF DAMAGE ON DRIFT LANDING.REUSABILITY OF AIRBAGS. TURN-AROUND COMPLICATIONS	3/18	LAUNCH INTEGRITY DURING T.O. RUN. LAUNCH SEPARATION	3/18
6	ACTIONS TO ALLEVIATE RISK	IMPROVE GLIDE PATH ACCURACY BY DIRECT LIFT CONTROL	5/30	← DITTO	5/30	DETAILED STUDY OF H.T.L. REQUIREMENTS & DETAIL DESIGN BUILD PROTOTYPES.	3/18	CONTINUOUS DEVELOPMENT OF EQUIPMENT ON VEHICLE REPRESENTATIVE OF ARPV SIZE & PAYLOAD	4/24	DETAILED STUDY. DETAILED DESIGN. PROTOTYPE DEVELOP.	3/18
10	MEETS MISSION REQUIREMENTS (SORTIE RATES, MOBILITY, SURVIVABILITY	POSITIVELY YES HIGH SORTIE RATES, HIGH MOBILITY, GOOD SURVIVAL	6/60	← DITTO	6/60	SHOULD MEET MISSION REQUIREMENTS	4/40	WILL NOT MEET HIGH SORTIE RATES ON CONTINUOUS BASIS UNLESS HIGH LAUNCHER/ VEHICLE RATIO IS USED	2/20	PROBABLY YES BUT DOLLY CONCEPT IS NORMALLY NOT CONDUCIVE TO HIGH SORTIE RATE	4/40
10	CAPABLE OF DEVELOPMENT WITHIN ARPV IOC	YES	6/60	← DITTO	6/60	YES	5/50	YES	6/60	YES	6/60
10	MEETS COSTS ESTIMATES	YES	6/60	DEPENDING ON SATS COST IN DEVELOPMENT	4/40	NEW COSTING REQUIRED AFTER DETAILED DESIGN	3/30	PROBABLY NOT RATO/TVC LAUNCHER TOO COSTLY	3/30	YES,BUT DOLLY GUIDANCE & RECOVERY COULD BE EXPENSIVE	5/50
6	CAN EVOLVE INTO ANOTHER TECHNICAL ALTERNATIVE	NO PROBLEM FOR DIRECT LIFT CONTROL. NO PROBLEM FOR ACLS.	5/30	DITTO AS WELL AS CONVENTIONAL T.O.	6/36	YES - INTO RAIL CATAPULT LAUNCH SYSTEM	4/24	NOT EASILY ZEL(TVC) IS A PECULIAR CONFIGURATION	3/18	NOT EASILY DOLLY CONCEPT DEMANDS SPECIAL HARDPOINTS & VEHICLE DESIGN	3/18
68								* THIS SYSTEM USED ONLY FOR COMPARISON			
			376 5.52 1		362 5.32 2		240 3.52 8		250 3.67 7		294 4.32 3

Analysis Matrix

2

L + WHEELED DOLLY RE GUIDED) + ARR R + SKIDS		STOL, WHEEL DOLLY STEERABLE + ARR GEAR INTEGRAL AIR CUSHION		SATS CATAPULT CONV. GEAR + ARR GEAR (NO STOL)		STOL + AIR CUSHION DOLLY + INTEGRAL AIR CUSHION + ARR GEAR		CATAPULT RAIL(RATO)+ MITT + EXTERNAL AIR MAT		DC-130 + MARS RECOVERY	
LED DOLLY IS ATE OF THE IN DIFFERENT ICATIONS. GUIDANCE OF L DOLLY IS	5/50	STEERABLE DOLLY IS A STATE OF THE ART USED IN JINDIVIK DRONE. INTEGRAL AIR CUSHION IS NOT IT IS IN EARLY, DEVELOPMENT	5/50	STATE OF THE ART WORLDWIDE	7/70	NOT A STATE OF THE ART - UNDER DEVELOPMENT	4/40	NOT A STATE OF THE ART - MINATURE SYSTEMS UNDER DEVELOPMENT	2/20	STATE OF THE ART	7/70
GRITY OF ANCE & ATABILITY HE SYSTEM- VERY OF Y AFTER CH	4/40	CONTROL OF DOLLY & RECOVERY. GROUND HANDLING OR AIR CUSHION. SYSTEM TURN AROUND TIME AFTER LANDING	3/30	PERMANENCE OF INSTALLATION - LONG STROKE COSTLY EQUIPMENT	3/30	ACLS-CONTROL, HANDLING, PERFORMANCE + TURN AROUND	3/30	BALLOONS HANDLING & SUPPORT EQUIPMENT. LOGISTICS, MAN POWER REQUIREMENTS	2/20	COMPLEX AND TEDIOUS OPERATION NOT FOR TACTICAL USE (IN LARGE NUMBERS)	3/30
CH INTEGRITY NG T.O. RUN. CH SEPARA-	3/18	INTEGRITY OF ACLS ON HIGH VELOCITY IMPACT. ABRASIVE DAMAGE WINTER OPERATION. INTERNAL SYSTEM DESIGN INTEGRITY	3/18	HIGHER KINETIC ENERGY LEVELS EFFECT ON VEHICLE	3/18	THERE ARE MANY. ONLY 3 SYSTEMS ARE ON A/C BUT ONLY ONE IS CLOSE TO BEING REPRESENTATIVE	3/18	NET & LATTICE CAPTURE BEHAVIOR. DAMAGE TO VEHICLE AND NET. DYNAMICS OF SYSTEM	3/18	CAPABILITY OF CARRIAGE OF ARPV WITH FULL MISSION LOAD. ENEMY REACTION	3/18
ILED STUDY. ILED GN. PROTO- DEVELOP.	3/18	COMPLETE THE DEVELOPMENT OF ACLS IN JINDIVIK. DEFINE OPERATING METHODS & MEASURE PERFORMANCE	5/30	COMPLETE DEVELOPMENT OF CATAPULT IN USAF TO PROVE ARPV SYSTEM	5/30	CONTINUE DEVELOPMENT OF JINDIVIK AND BUFFALO	5/30	PERFORM SIMULATION STUDY OF MITT CONCEPT. DEFINE LIMITATIONS & BENEFITS	4/24	SYSTEM IS DEVELOPED. SIMPLIFY EXISTING SYSTEM	3/18
ABLY YES DOLLY EPT IS ALLY NOT UCIVE TO SORTIE	4/40	PROBABLY YES, BUT ACLS WILL BE DIFFICULT TO HANDLE ON TURN-AROUND IF ALSO T.O. DOLLY IS INVOLVED	3/30	PROBABLY YES, BUT LONGER STROKE, HIGH T.O. SPEED MAY BE DETRIMENTAL	3/30	PROBABLY NOT. HANDLING & TURN-AROUND OF AC DOLLY & INTEGRAL A/C IS DIFFICULT IN TIME	2/20	PROBABLY NOT BUT COULD ACT AS LAST RESORT RECOVERY SYSTEM	2/20	WILL NOT MEET THE SORTIE RATES REQUIRED.	1/10
YES	6/60	PROBABLY YES	5/50	YES, BUT MAY BE NOT THE BEST METHOD	5/50	PROBABLY YES	5/50	AS A TACTICAL SYSTEM PROBABLY NOT. MANY PROBLEMS AHEAD	3/30	YES, BUT NOT THE BEST METHOD	5/50
BUT Y GUID- & VERY D BE NSIVE	5/50	PROBABLY YES, BUT ACLS HANDLING PROBLEMS MAY AGGRAVATE THE ACHIEVEMENT OF GOALS	4/40	PROBABLY NOT. SYSTEM NEEDS NEW APPROACH FOR ARPV	3/30	PROBABLY YES, BUT ACLS WITH DROPPABLE DOLLY MAY PROVE DIFFICULT & COSTLY	3/30	PROBABLY NOT HELIUM AND ITS TANKS ARE VERY EXPENSIVE	2/20	PROBABLY NOT. VERY COSTLY METHOD	2/20
EASILY Y CON- DEMANDS IAL HARD- TS & CLE DESIGN	3/18	PROBABLY NOT THE ACLS DEMANDS SPECIAL DESIGN TREATMENT FROM VEHICLE	2/12	YES. RAIL CATAPULT(RATO). CONVENTIONAL T.O. WILL NOT BE SATISFACTORY	3/18	DEFINITELY NOT THIS IS ONE OF A KIND DESIGN	1/6	YES. CAN ACT AS LAST RESORT RECOVERY SYSTEM	6/36	YES FOR SAC USAGE	6/36
						*THIS SYSTEM USED ONLY FOR COMPARISON		*THIS SYSTEM NOT TYPICAL SELECTED AS POSSIBLE ALTERNATIVE FOR RECOVERY		*THIS SYSTEM USED ONLY FOR COMPARISON	
	294 4.32 3		260 3.82 5		276 4.05 4		224 3.29 9		188 2.76 10		252 3.70 6

3.82 #5 STOL + WHEELED DOLLY(STEERABLE) + ARRESTER GEAR + INTEGRAL AIR CUSHION

3.52 #6 STOL + HYBRID TRUCK LAUNCHER + ARRESTER GEAR + SKIDS

(Other four systems were not selected for final evaluation, and were only used for comparison.)

In proceeding to normalize the Risk F.O.M.'s with respect to the average Risk F.O.M. = 4.37, the following table is obtained.

SYSTEM NO.	NORMALIZED RISK F.O.M.	
#1	1.247	LEAST RISK
#2	1.20	
#3	0.97	AVERAGE RISK
#4	0.91	
#5	0.86	
#6	0.79	MOST RISK

Using the Normalized Risk F.O.M. as a multiplier in conjunction with Cost/Benefits F.O.M.'s from Table 6.3-1 , a first combined Cost/Benefits/Risk assessment was obtained with the ranks assigned to each system.

The final list reads as follows:

FINAL COST/BENEFITS/RISK RANKING

FINAL RANK	SYSTEM		FINAL F.O.M. COMBINED
#1	STOL + CONVENTIONAL GEAR + ARRESTER GEAR	1.247 x 3.0 =	3.741
#2	STOL + SATS CATAPULT(MOD) + CONV GEAR + ARRESTER GEAR	1.20 x 2.09 =	2.50
#3	STOL + WHEELED DOLLY(WIRE GUIDED) + ARRESTER GEAR + SKIDS	0.97 x 2.19 =	2.12
#4	BASIC WING + SATS CATAPULT(MOD) + CONV GEAR + ARRESTER GEAR	0.91 x 2.08 =	1.89
#5	STOL + WHEELED DOLLY(STEERABLE) + ARRESTER GEAR + INTEGRAL AIR CUSHION	0.86 x 2.20 =	1.89
#6	STOL + HYBRID TRUCK LAUNCHER + ARRESTER GEAR + SKIDS	0.79 x 1.61 =	1.27

The histogram of the F.O.M. values, the average, and the standard deviations are plotted in Figure 6.3-1 .

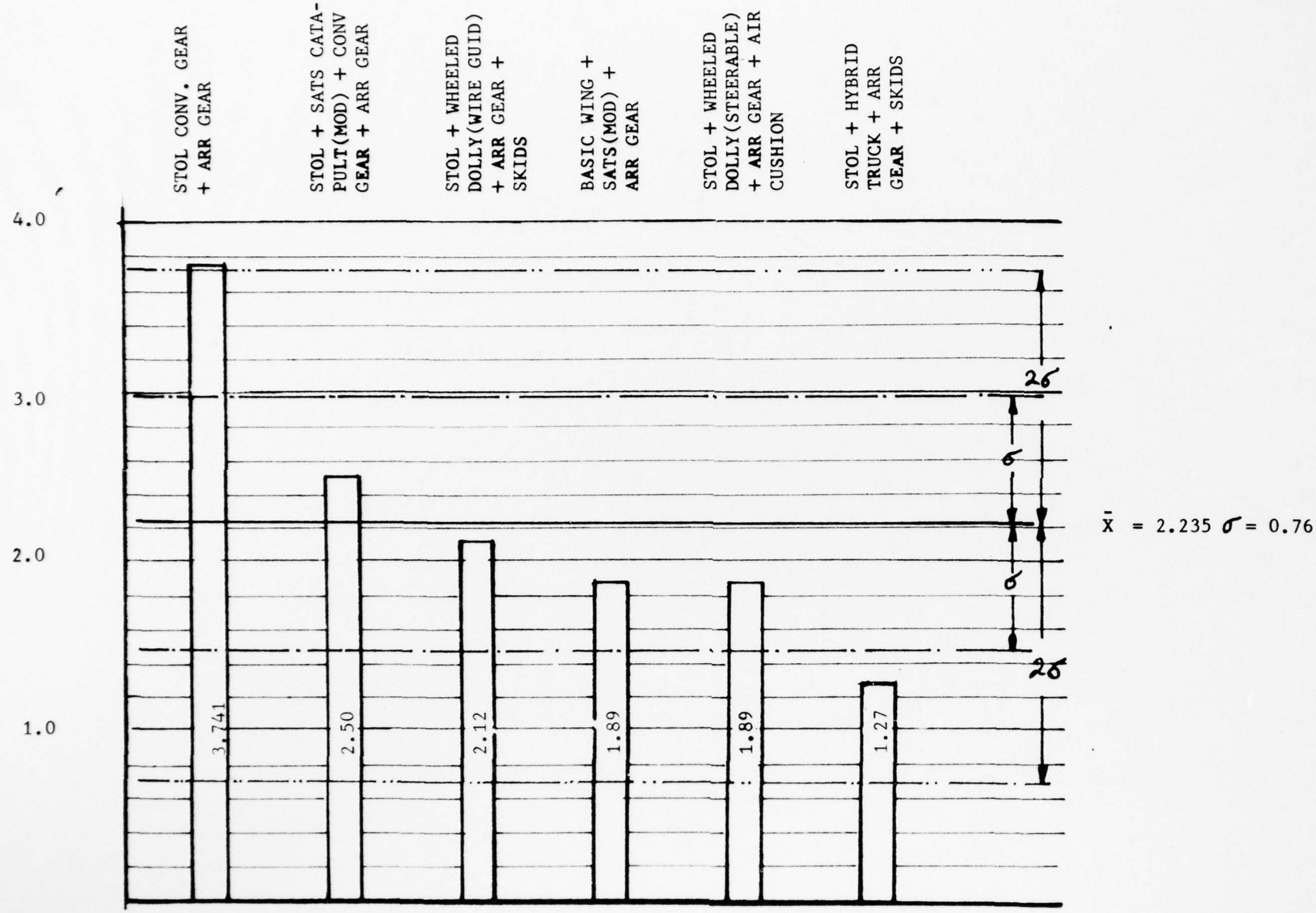


Figure 6.3-1. Final Ranking

7.0 CONCLUSIONS

On the basis of trade-off analysis of Launch and Recovery Systems for ARPV, the conventional take-off and landing method using high lift wing (STOL) technique, own thrust and arresting gear system emerged as the undisputable leader among the candidate systems.

The next system in succession is the STOL configuration using modified SATS catapult conventional gear and arrester gear. This system is contingent upon availability of SURPLUS SATS catapults. It looses its precedence if such catapults are not available for relatively low cost mods. This would also apply to the system #4. In such event, the second best system becomes STOL + WHEELED DOLLY(AUTOMATICALLY WIRE GUIDED) + ARRESTER GEAR + SKIDS. (This system is not unlike the basic JINDIVIK System except for STOL, wire guidance and vehicle arrestment by arrester gear.

The third best system comes out to be a STOL CONFIGURATION + WHEELED DOLLY (STEERABLE) + ARRESTER GEAR AND INTEGRAL AIR CUSHION.

In the fourth place (again in absence of cheap SATS catapults), the Hybrid Truck Launcher with STOL and Arrester Gear + SKIDS is the final viable candidate which can be effective as a tactical ARPV system Launch and Recovery Method.

The next series of trade-off studies address the selection of the optimum launch and recovery systems within the general terms of conventional take-off and arrested landing in a STOL (high lift) configuration. These trade studies were performed prior to the definition of the baseline system and constituted a part of the preferred system selection. The subjects which were addressed were as follows:

1. High Floatation Gear vs Conventional Tri-Cycle Gear
2. Sheaffer Tail Hook vs Conventional Tail Hook

3. One Pendant vs Multi-Pendant Arresting System (24" water twister)
4. Layout of RPV Base for Intermittent VS Continuous Operation
5. Two-Stage Flare vs No-Flare On Approach
6. Nose Wheel Troughs vs Other Heading Hold Devices
7. Jeep With Tow Bar vs Tractor and Tow Bar
8. Matting AM2 vs Steel Matting VS No Matting
9. Separate Control Van for Launch and Recovery vs Combined L&R Van
10. Manual Override of Vehicle Control on Approach vs No Override
11. Employment of Safety Barrier vs No Barrier
12. Launch and Recovery Control Trade-Offs

All of the above trade studies will be presented in the Launch and Recovery Volume of the Final Report.

The Preferred L&R System

The system selected for the ARPV on the basis of the above studies is a conventional take-off and landing mode using a tricycle, retractable, high floatation gear in conjunction with high lift generating wings. The high lift wing employs a symmetrical airfoil with a leading edge and trailing edge droop for short take-off and low approach speeds. Three external equipments are used: On take-off, a heading alignment trough, which keeps the nose wheel constrained to a take heading until 50 KTS is reached, and on landing, an arrester gear backed by a safety barrier for emergency overruns.

The recovery heading and glide path precision control is vested in a microwave landing system (MLS) with an on-board interpretative control over the vehicle and its thrust, on the glide path, until touch down. A manual back-up control system is provided in the event of primary mode control failure.

APPENDIX

TO

VOL. IV

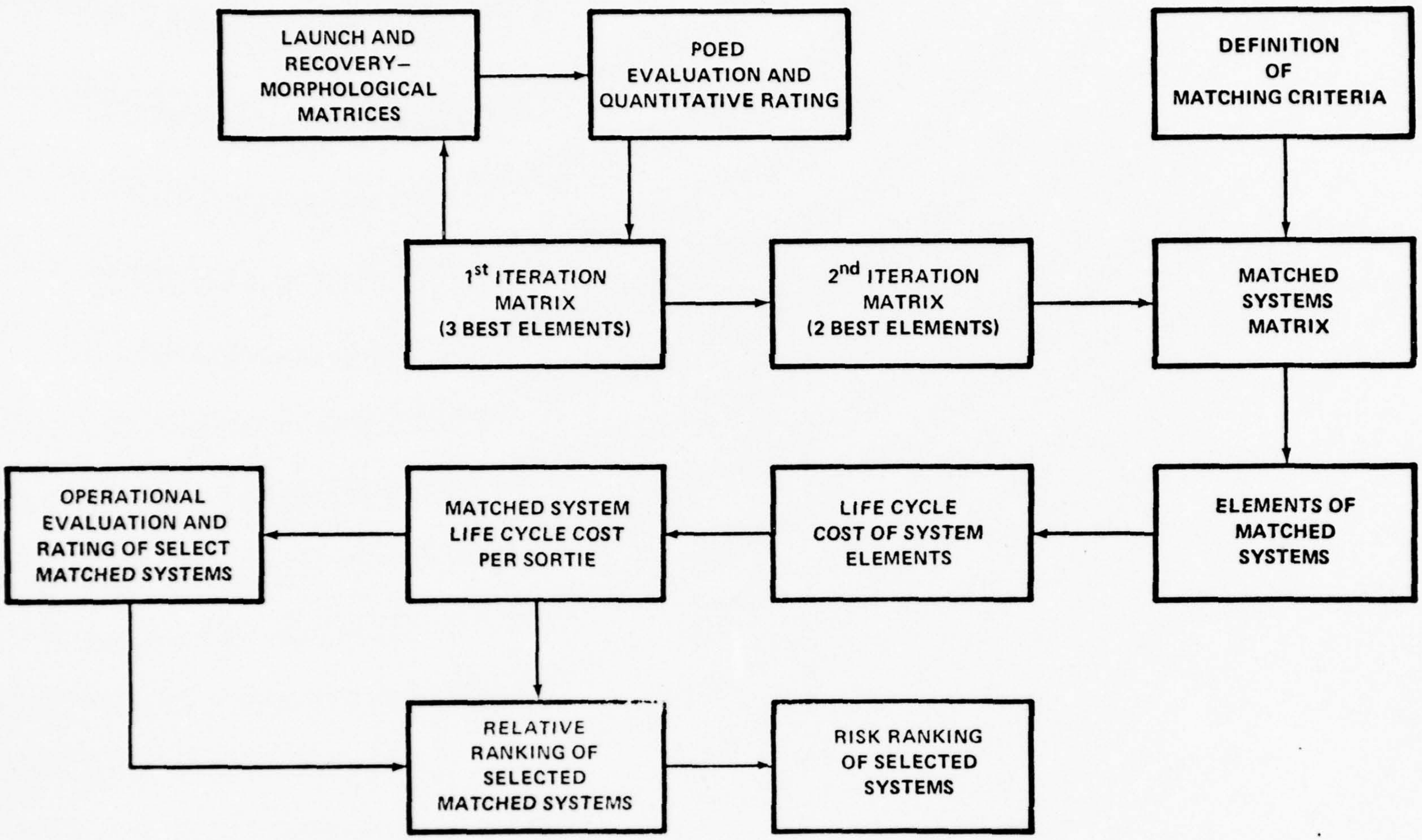
LAUNCH & RECOVERY

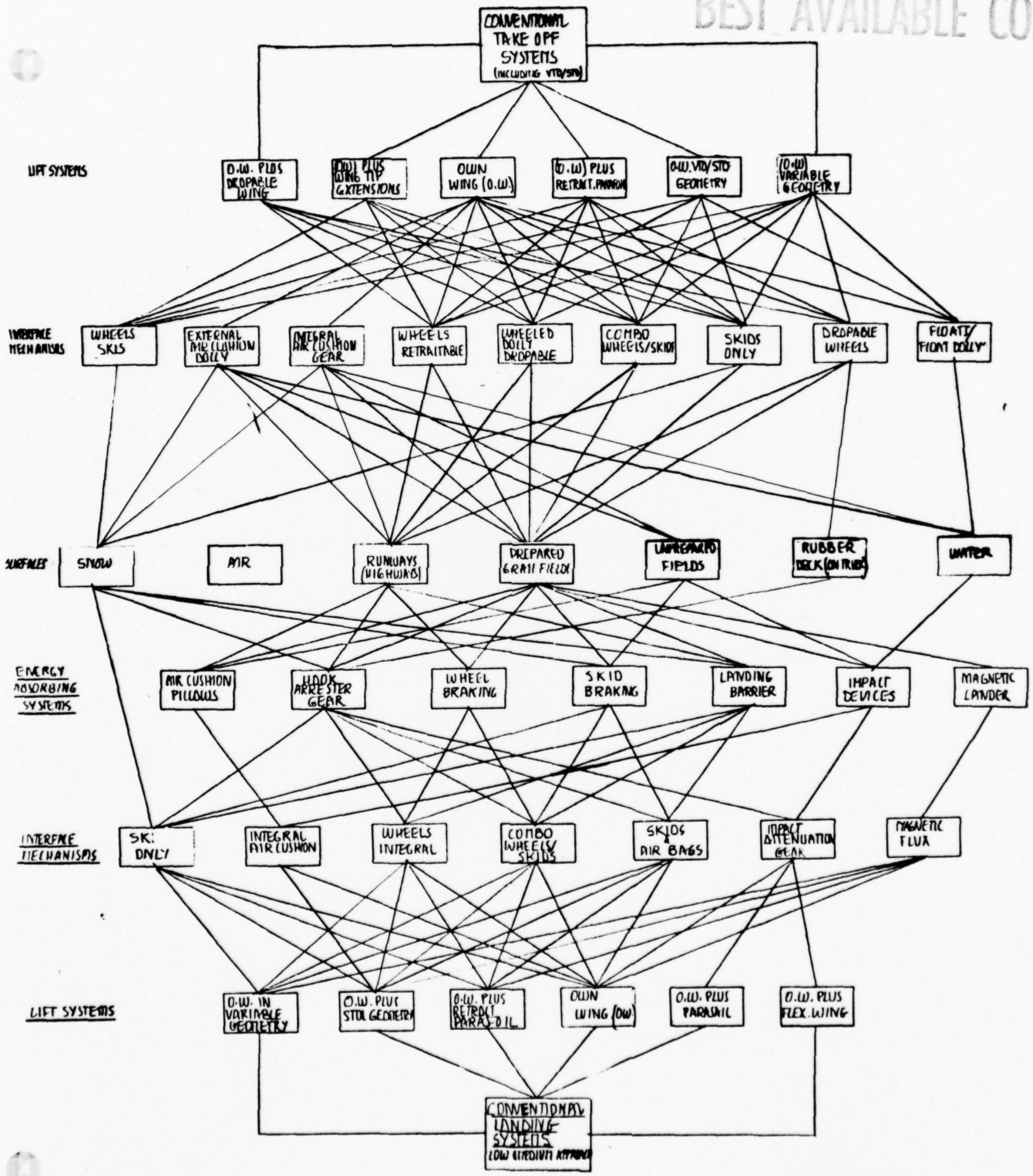
EVALUATION

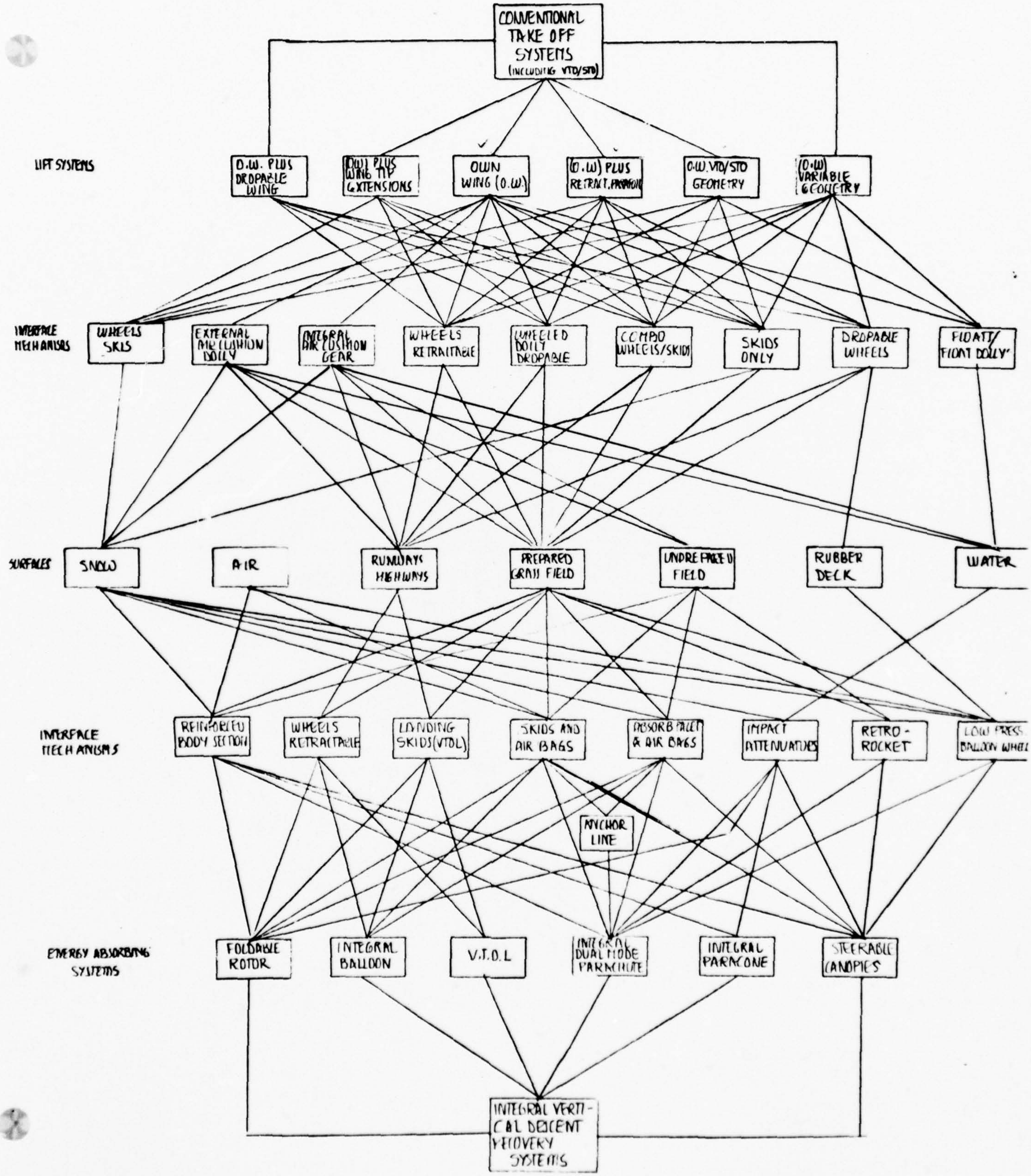
&

SELECTION PROCESS

LAUNCH AND RECOVERY SYSTEM EVALUATION AND SELECTION PROCESS




CONVENTIONAL TAKE OFF SYSTEMS (INCLUDING VTO/STO)
LIFT SYSTEMS
O.W. PLUS DROPABLE WING
(O.W.) PLUS WING TIP EXTENSIONS
OWN WING (O.W.)
(O.W.) PLUS RETRACT. PARAFOIL
O.W. VTO/STO GEOMETRY
(O.W.) VARIABLE GEOMETRY
INTERFACE MECHANISMS
WHEELS SKIS
EXTERNAL AIR CUSHION DOLLY
INTEGRAL AIR CUSHION GEAR
WHEELS RETRACTABLE
WHEELED DOLLY DROPABLE
COMBO WHEELS/SKIDS
SKIDS ONLY
DROPABLE WHEELS
FLOATS/ FLOAT DOLLY
SURFACES
SNOW
AIR
RUNWAYS (HIGHWAYS)
PREPARED GRASS FIELDS
UNPREPARED FIELDS
RUBBER DECK (ON TRUCK)
WATER
ENERGY ABSORBING SYSTEMS
AIR CUSHION PILLOWS
HOOK ARRESTER GEAR
WHEEL BRAKING
SKID BRAKING
LANDING BARRIER
IMPACT DEVICES
MAGNETIC LANDER
INTERFACE MECHANISMS
SKIS ONLY
INTEGRAL AIR CUSHION
WHEELS INTEGRAL
COMBO WHEELS/ SKIDS
SKIDS & AIR BAGS
IMPACT ATTENUATION GEAR
MAGNETIC FLUX
LIFT SYSTEMS
O.W. IN VARIABLE GEOMETRY
O.W. PLUS STOL GEOMETRY
O.W. PLUS RETRACT PARAFOIL
OWN WING (OW)
O.W. PLUS PARASAIL
O.W. PLUS FLEX. WING
CONVENTIONAL LANDING SYSTEMS
LOW (MEDIUM APPROACH)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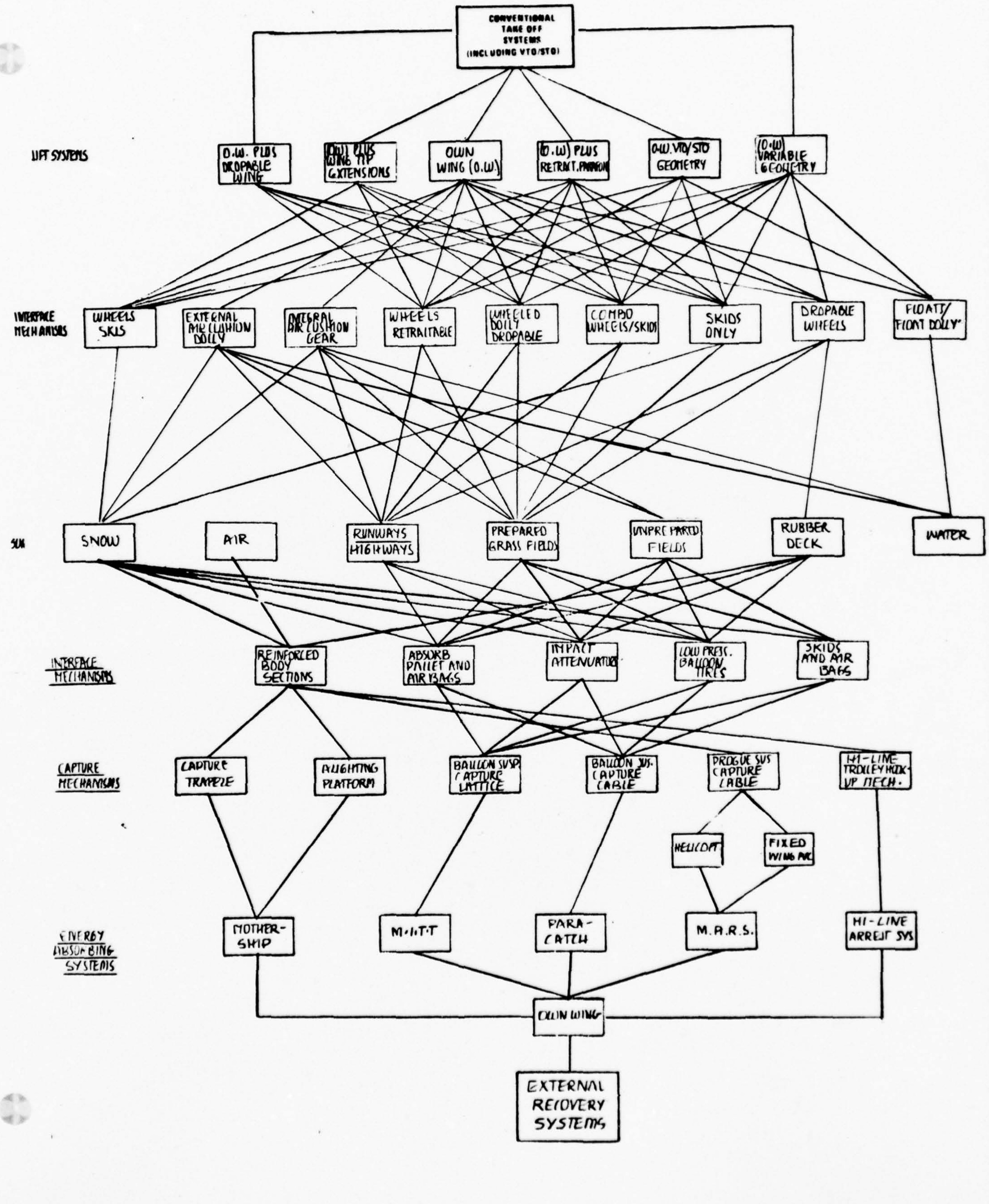
SURFACES
SNOW
AIR
RUNWAYS HIGHWAYS
PREPARED GRASS FIELD
UNPREPARED FIELD
RUBBER DECK
WATER
INTERFACE MECHANISMS
REINFORCED BODY SECTION
WHEELS RETRACTABLE
LANDING SKIDS (VTOL)
SKIDS AND AIR BAGS
ABSORB PALLET & AIR BAGS
IMPACT ATTENUATORS
RETRO-ROCKET
LOW PRESS. BALLOON WHEEL
ANCHOR LINE
ENERGY ABSORBING SYSTEMS
FOLDABLE ROTOR
INTEGRAL BALLOON
V.T.O.L
INTEGRAL DUAL MODE PARACHUTE
INTEGRAL PARACONE
STEERABLE CANOPIES
INTEGRAL VERTICAL DESCENT RECOVERY SYSTEMS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O.W. VTO/STO GEOMETRY
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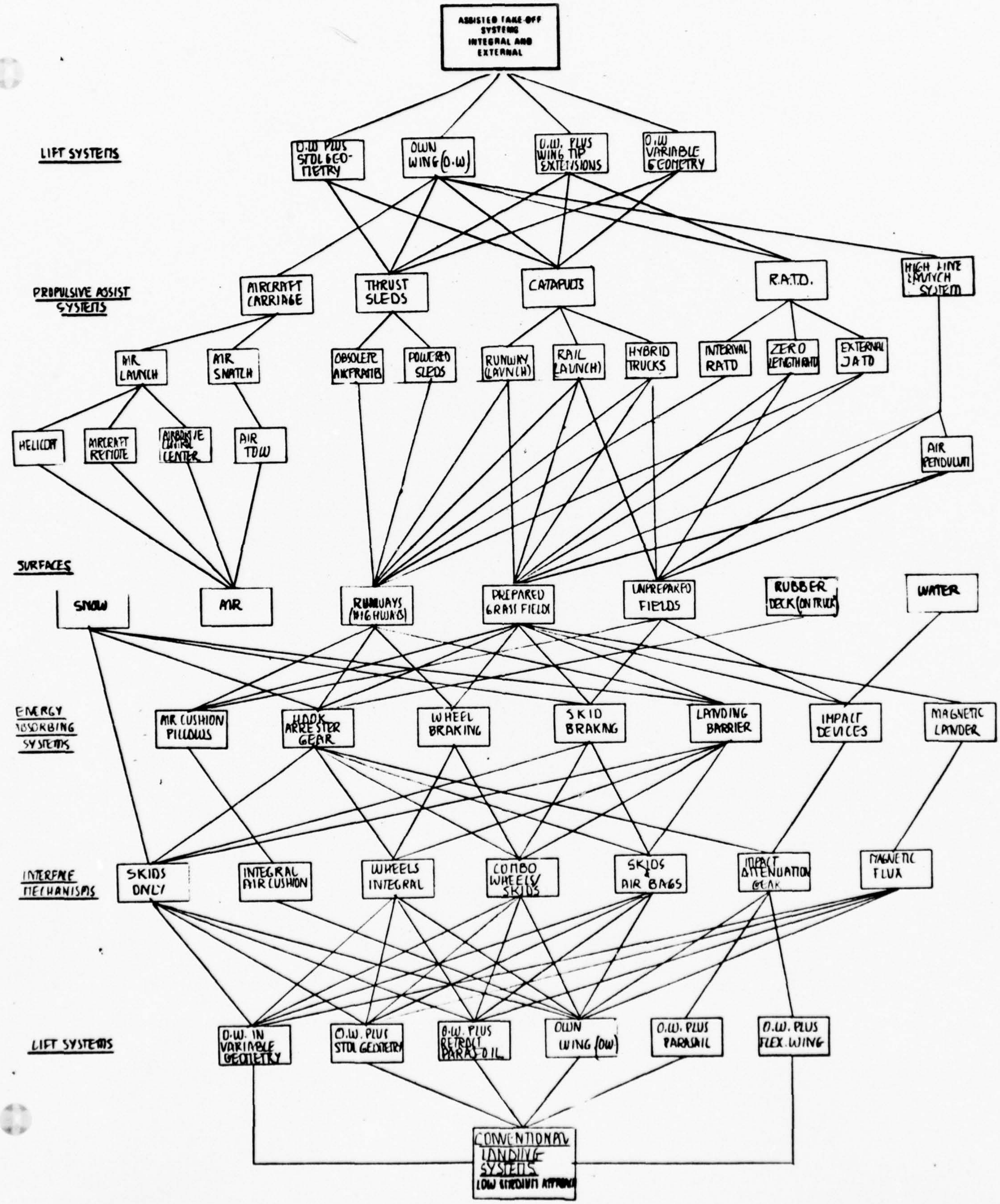
WHEELS SKIS
EXTERNAL AIR CUSHION DOLLY
INTEGRAL AIR CUSHION GEAR
WHEELS RETRACTABLE
WHEELED DOLLY DROPABLE
COMBO WHEELS/SKIDS
SKIDS ONLY
DROPABLE WHEELS
FLOAT/ "FLOAT DOLLY"
SNOW
AIR
RUNWAYS HIGHWAYS
PREPARED GRASS FIELDS
UNPREPARED FIELDS
RUBBER DECK
WATER
INTERFACE MECHANISMS
REINFORCED BODY SECTIONS
ABSORB PALLET AND AIR BAGS
IMPACT ATTENUATOR
LOW PRESS. BALLOON TIRES
SKIDS AND AIR BAGS
CAPTURE MECHANISMS
CAPTURE TRAPEZE
ALIGHTING PLATFORM
BALLOON SUSP. CAPTURE LATTICE
BALLOON SUS. CAPTURE CABLE
DROGUE SUS CAPTURE CABLE
HI-LINE TROLLEY HOOK-UP MECH.
HELICOPT
FIXED WING A/C
ENERGY ABSORBING SYSTEMS
MOTHER-SHIP
M.I.T.T
PARA-CATCH
M.A.R.S.
HI-LINE ARREST SYS
OWN WING
EXTERNAL RECOVERY SYSTEMS


ASSISTED TAKE-OFF SYSTEMS INTEGRAL AND EXTERNAL
LIFT SYSTEMS
O.W PLUS STOL GEOMETRY
OWN WING (O.W)
O.W. PLUS WING TIP EXTENSIONS
O.W VARIABLE GEOMETRY
PROPULSIVE ASSIST SYSTEMS
AIRCRAFT CARRIAGE
THRUST SLEDS
CATAPULTS
R.A.T.O.
HIGH LINE LAUNCH SYSTEM
AIR LAUNCH
AIR SNATCH
OBSOLETE AIRFRAME
POWERED SLEDS
RUNWAY (LAUNCH)
RAIL LAUNCH)
HYBRID TRUCKS
INTERNAL RATO
ZERO LENGTH RATO
EXTERNAL JATO
HELICOPT
AIRCRAFT REMOTE
AIRBORNE CONTROL CENTER
AIR TOW
AIR PENDULUM
SURFACES
SNOW
AIR
RUNWAYS (HIGHWAYS)
PREPARED GRASS FIELDS
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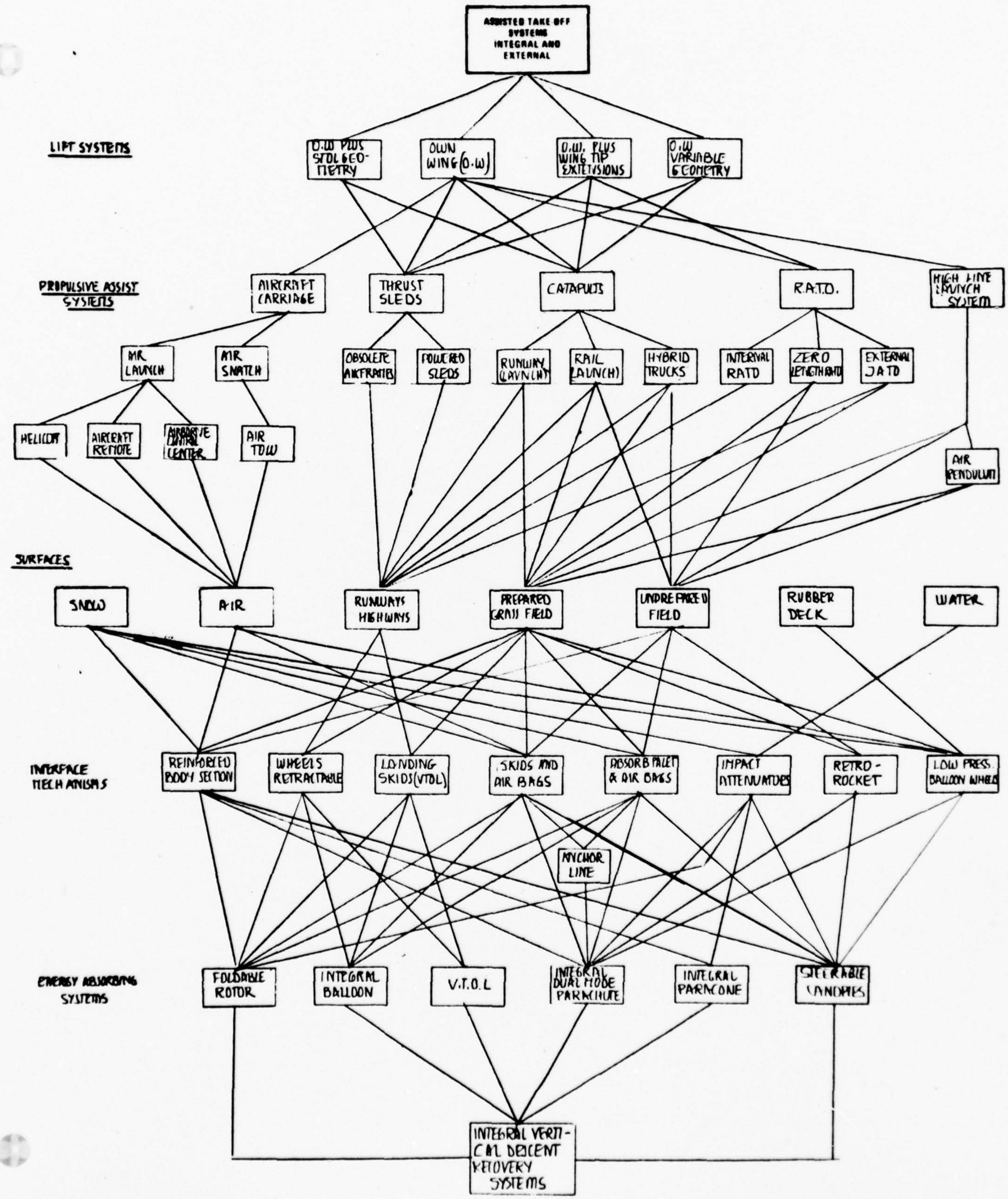
O.W. PLUS FLEX. WING
CONVENTIONAL LANDING SYSTEMS
LOW STEEP APPROACH


ASSISTED TAKE OFF SYSTEMS INTEGRAL AND EXTERNAL
LIFT SYSTEMS
O.W PLUS STOL GEOMETRY
OWN WING (O.W)
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O.W VARIABLE GEOMETRY
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AIRCRAFT CARRIAGE
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CATAPULTS
R.A.T.O.
HIGH LINE LAUNCH SYSTEM
AIR LAUNCH
AIR SNATCH
OBSOLETE AIRFRAMES
POWERED SLEDS
RUNWAY LAUNCH
RAIL LAUNCH
HYBRID TRUCKS
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EXTERNAL JATO
HELICOPT
AIRCRAFT REMOTE
AIRBORNE CONTROL CENTER
AIR TOW
AIR PENDULUM
SURFACES
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AIR
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IMPACT ATTENUATORS
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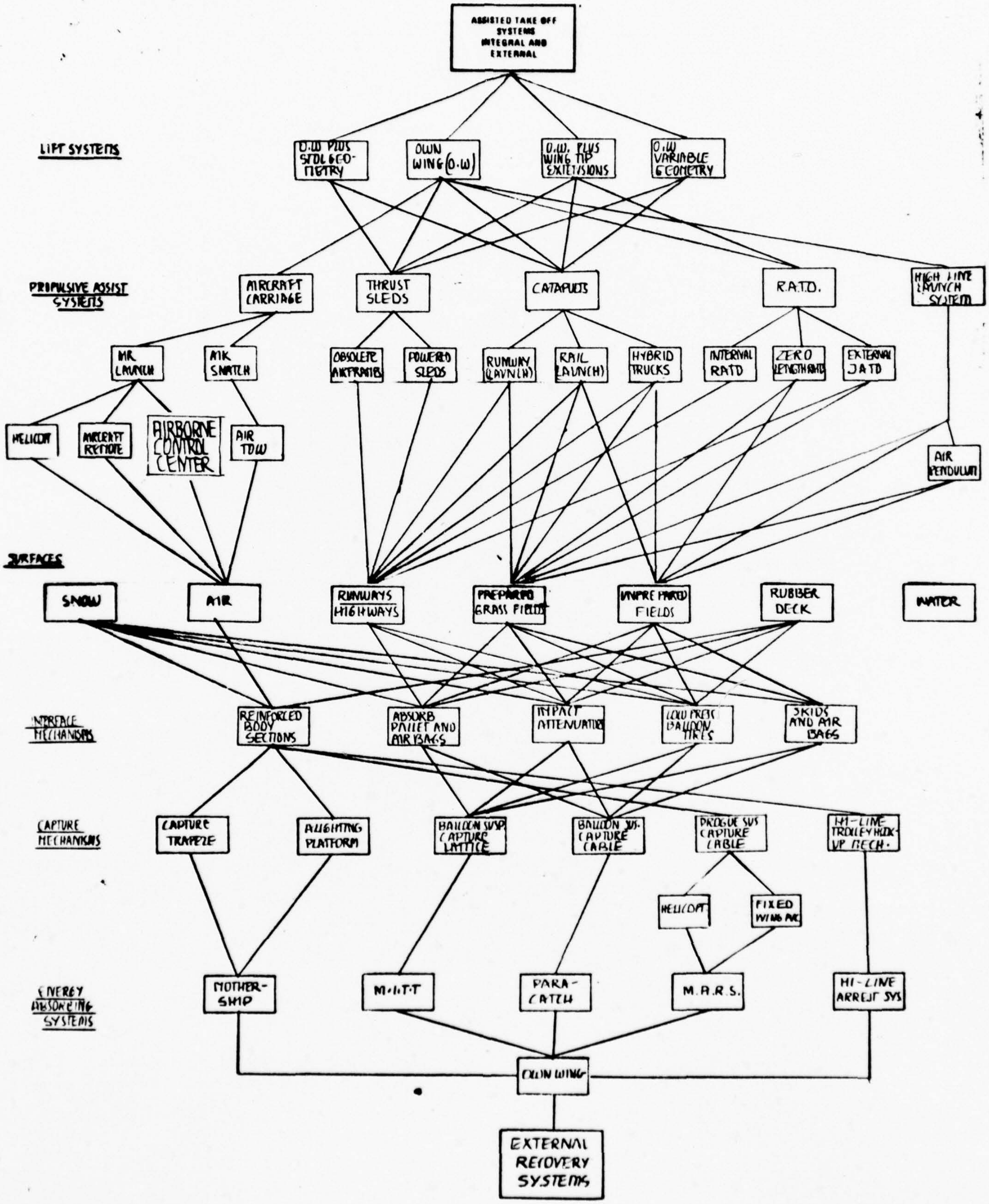
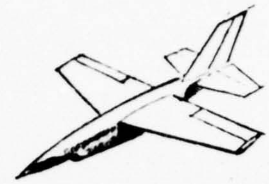
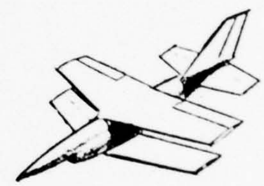
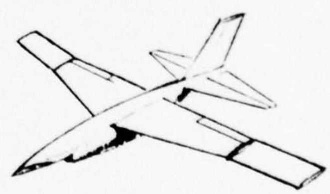
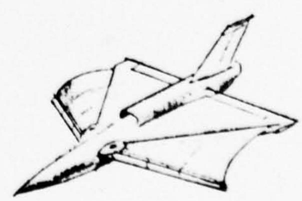
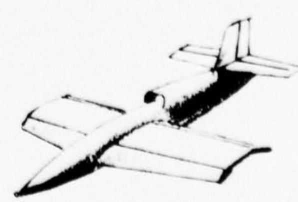
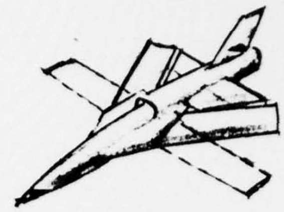
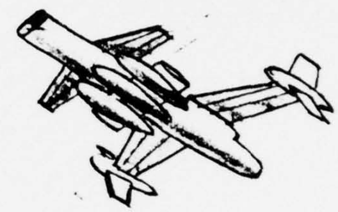
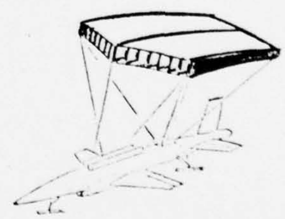
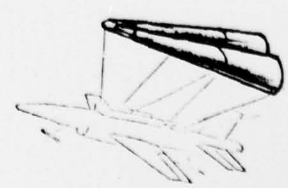
LOW PRESS. BALLOON WHEELS
ANCHOR LINE
ENERGY ABSORBING SYSTEMS
FOLDABLE ROTOR
INTEGRAL BALLOON
V.T.O.L
INTEGRAL DUAL MODE PARACHUTE
INTEGRAL PARACONE
STEERABLE CANOPIES
INTEGRAL VERTICAL DESCENT RECOVERY SYSTEMS


ASSISTED TAKE OFF SYSTEMS INTEGRAL AND EXTERNAL
LIFT SYSTEMS
O.W PLUS STOL GEOMETRY
OWN WING (O.W)
O.W. PLUS WING TIP EXTENSIONS
O.W VARIABLE GEOMETRY
PROPULSIVE ASSIST SYSTEMS
AIRCRAFT CARRIAGE
THRUST SLEDS
CATAPULTS
R.A.T.O.
HIGH LINE LAUNCH SYSTEM
AIR LAUNCH
AIR SNATCH
OBSOLETE AIRFRAMES
POWERED SLEDS
RUNWAY LAUNCH
RAIL LAUNCH
HYBRID TRUCKS
INTERNAL RATO
ZERO LENGTH
EXTERNAL JATO
HELICOPT
AIRCRAFT REMOTE
AIRBORNE CONTROL CENTER
AIR TOW
AIR PENDULUM
SURFACES
SNOW
AIR
RUNWAYS HIGHWAYS
PREPARED GRASS FIELDS
UNPREPARED FIELDS
RUBBER DECK
WATER
INTERFACE MECHANISMS
REINFORCED BODY SECTIONS
ABSORB PALLET AND AIR BAGS
IMPACT ATTENUATOR
LOW PRESS BALLOON TIRES
SKIDS AND AIR BAGS
CAPTURE MECHANISMS
CAPTURE TRAPEZE
ALIGHTING PLATFORM
BALLOON SUSP CAPTURE LATTICE
BALLOON SUS. CAPTURE CABLE
DROGUE SUS CAPTURE CABLE
HI-LINE TROLLEY HOOK-UP MECH.
HELICOPT
FIXED WING A/C
ENERGY ABSORBING SYSTEMS
MOTHER-SHIP
M.I.T.T
PARA-CATCH
M.A.R.S.
HI-LINE ARREST SYS
OWN WING
EXTERNAL RECOVERY SYSTEMS

GLOSSARY OF TERMS

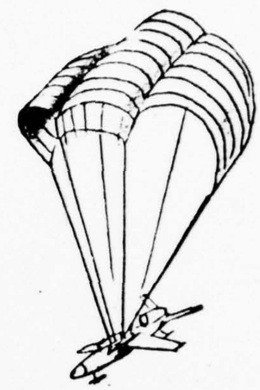
GLOSSARY OF TERMS

ELEMENT	DESCRIPTION	
Own Wing	Basic vehicle wing without additions which increase lift	
Own Wing - plus Droppable Wing	A configuration of biplane or multiplane wings - one of which remains with the vehicle throughout the mission, while others are discarded after launch and float to the ground	
Own Wing - plus Wing-Tip Extensions	Extendable wing tips are added to the basic wing in order to increase wing span and area for take-off. The wing-tips are separated after reaching safety speed by explosive bolts. They are repairable and reusable.	
Own Wing - plus Retractable (Stratowing) Parafoil	This configuration also known as Stratowing (Fairchild) uses flexible leading edge wing extensions to obtain lift increase during launch. After launch - the system reverts to basic configuration.	
Own Wing - Plus STOL Geometry	In a final assessment a variable profile wing without blowing using both the leading edge and trailing edge droop flaps. (Originally blowing concept was considered).	

Variable Geometry Wing	Variable sweep wing - near straight leading edge for take-off - highly swept for mission phase.	
V.T.O.	Vertical Take-Off System - Any V.T.O. system can fall under this category - such as augmentor wing, tail sitter, deflected nozzle jets, rotatable ducted fans, fans in the wing, stowable rotor, etc. In this study the augmentor wing VTO system was only assessed based on the configuration of XVF-12A (Rockwell.)	
Parasail Also known as Parafoil	It is a flying wing made entirely with nylon cloth with no rigid members. It has an upper and lower surface in the shape of an airfoil section. The ram air enters the leading edge which is open to permit inflation of the integral wing cells by ram air pressure. It is packed and deployed as an ordinary parachute. The maximum lift drag/ratio obtained with this device is estimated to be about five, giving the glide angle of approximately 11 degrees. (Reference: A Review of Parafoil Applications, T. D. Nicolaides, et al) T. of A. Sept-Oct, 1970	
Flexible Wing (Rogallo)	An inflated frame flexible wing packaged in the top of the RPV body. Lift/drag ratios vary between 3.0 to 4.0. Used for recovery only to reduce the landing speed of the vehicle to 100 ft/sec (60 kts.)	

Parawing

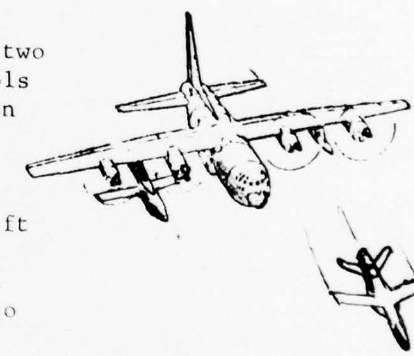
A completely flexible flying wing consisting of a rectangular center section with two isosceles - triangle outer sections. Usually numerous suspension lines are attached to the wing canopy in order to stabilize it during deployment. The canopy is constructed of nylon cloth. The weight of a typical RPV (400 ft^2) is about 26 lbs with a pack assembly weight of approximately 45 lbs and volume of 1.27 feet cubic. Approximately Lift/Drag Ratio = 3.0. (Developed by NASA Langley Research Center)



Air Launch

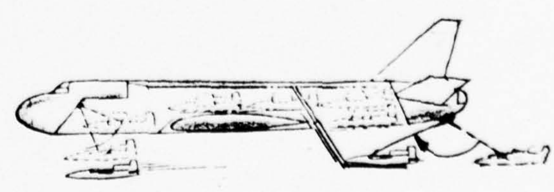
By Control Aircraft - DC-130H carries two to four RPVs, launches them and controls their mission from the airborne station present in the aircraft.

By Remote Aircraft - The launch aircraft does not control the RPV after launch. Upon launch of the required contingent of RPVs, the launch aircraft returns to base.



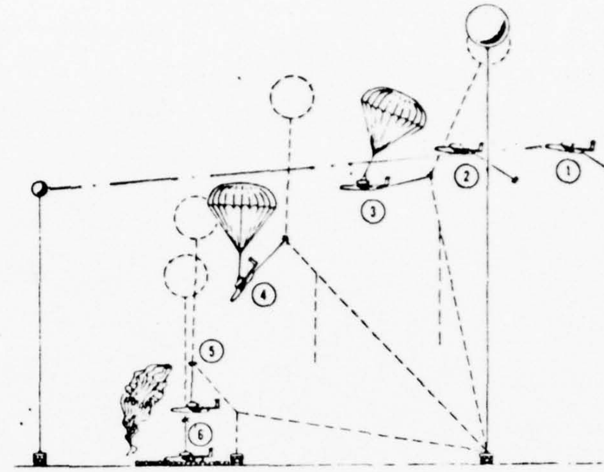
Mothership - Air Launch and Air Recovery

In this concept several RPVs are carried onboard the mothership which performs launch and recovery. RPVs can also be recovered by mothership if they were launched by remote aircraft. The candidate aircraft are all wide body aircraft including C-5A. The turn-around is carried out after landing.

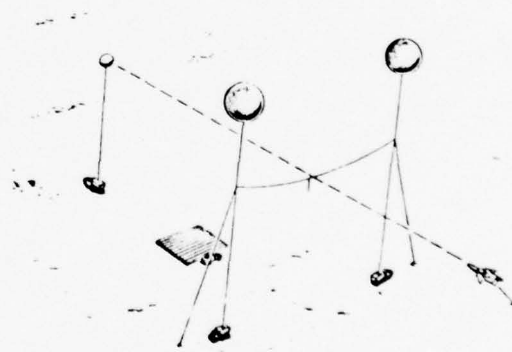


Paracatch

RPV, extending a floating grapnel engages a catenery of a cable stretched between a pair of helium balloons on each side. Parachute is deployed on engagement and the vehicle falls under the drag of the parachute and the buoyancy force of balloons. Parachute is jettisoned when the snubbing device senses vertical force of balloon to exceed that of parachute. The landing is on a rubber mat and retrieval of the RPV is made by a lift transporter.

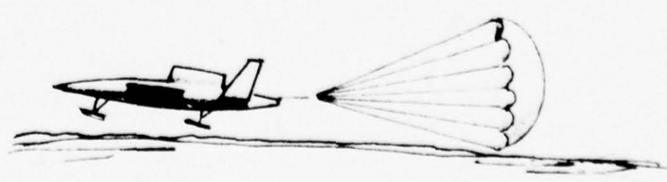


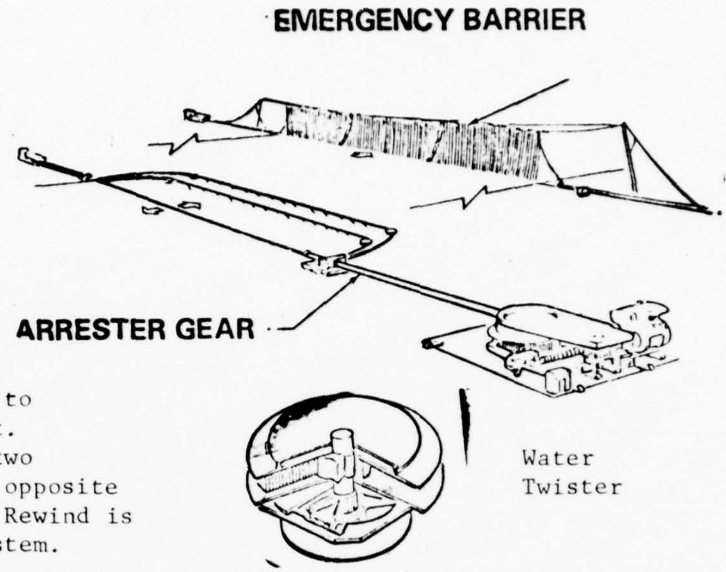
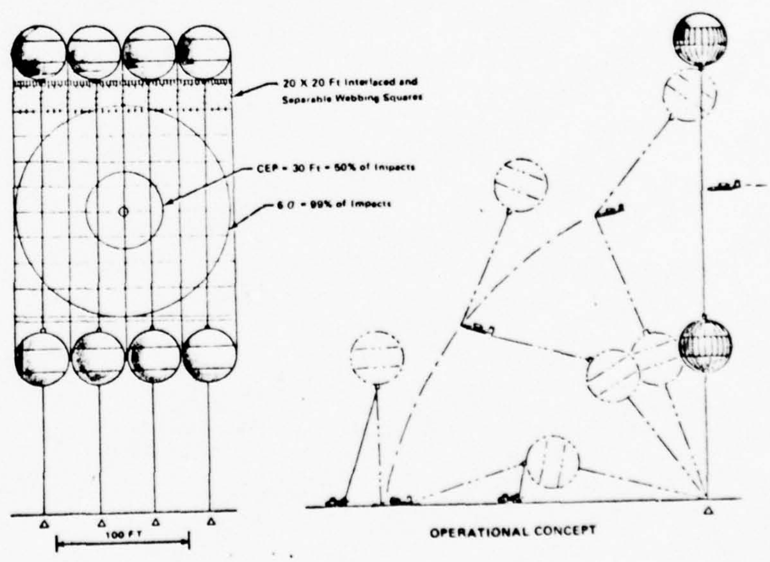
The deployment of the parachute after grapnel engagement is speeded up by the pyrotechnic means.



Parabrake

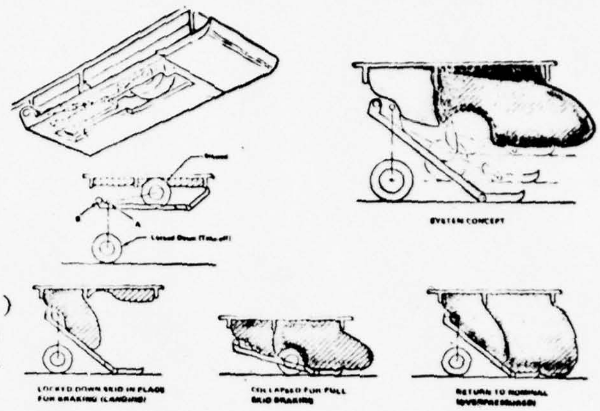
Retarding parachute deployed just prior to or at touch-down.



Water Twister Arrester Gear and Emergency Barrier	System that converts kinetic energy to heat through turbulence. Centrifugal rotor rotates within steel casing filled with fluid (glycol and water) against internal stator vanes. Nylon tape is wrapped on storage reel which is spliced to top end of rotor shaft. Steel cable connects two arresting twisters on opposite side of landing run. Rewind is by power retriever system.	
Mid Air Intercept and Terminal Trap MITT	Based on the combined effects of helium balloons buoyancy and their aerodynamic drag. It consists of eight balloons (approximately 40 ft diameter) a system of anchor cables, an interlaced nonelastic lattice segment and ground operating equipment with an air mat.	

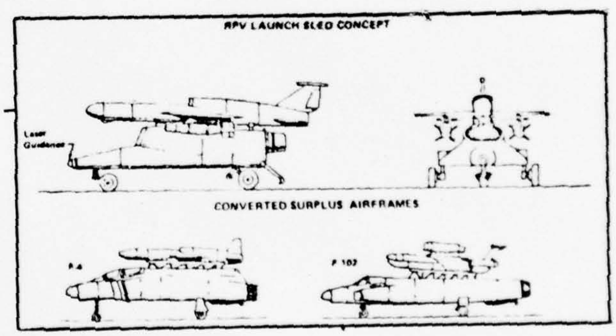
Wheels/Skid Combo Retardation System

Wheel and large retractable skid operate in conjunction with each other. Wheels are used for take-off, skids and wheels for landing and braking. Two separate airbags act on the skid for normal braking (1 bag) or emergency braking (2 bags.) After coming to a stop the vehicle is raised by over-inflation of airbags and locking of the gear in fully extended position.



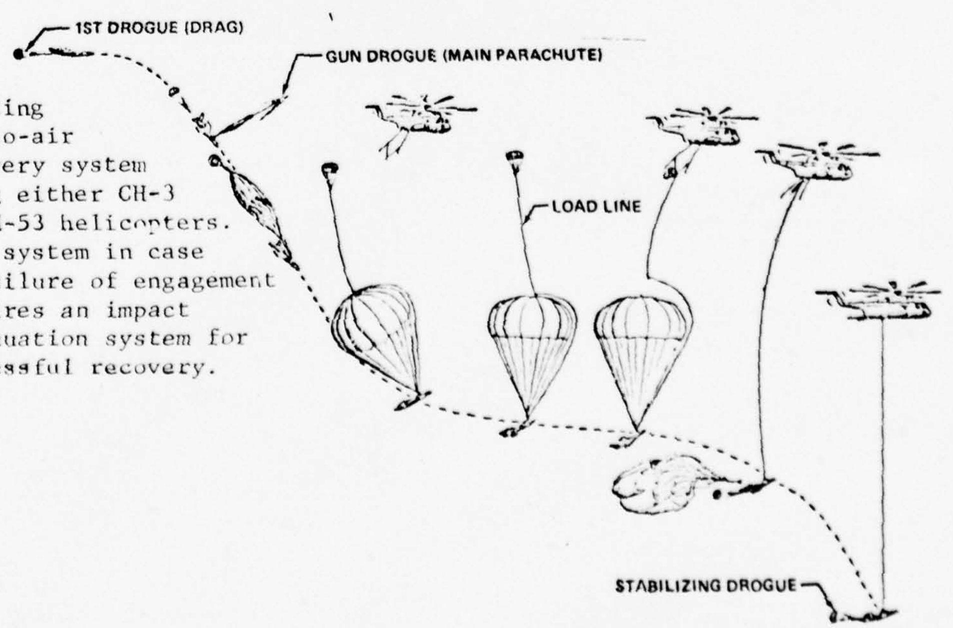
Powered Sleds and Obsolete Airframes

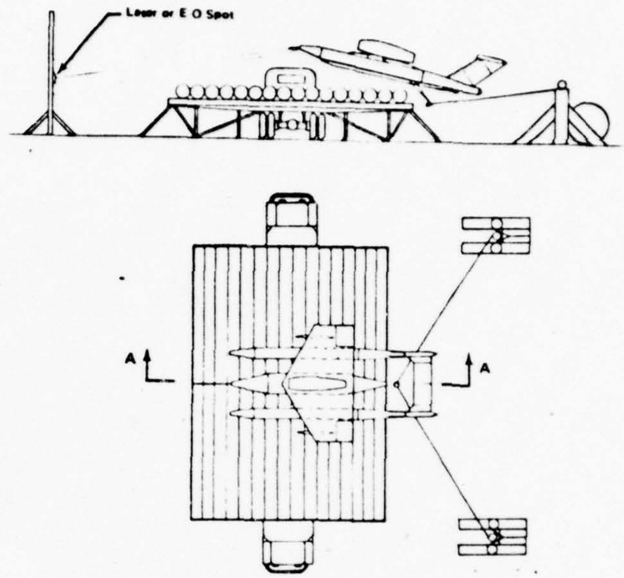
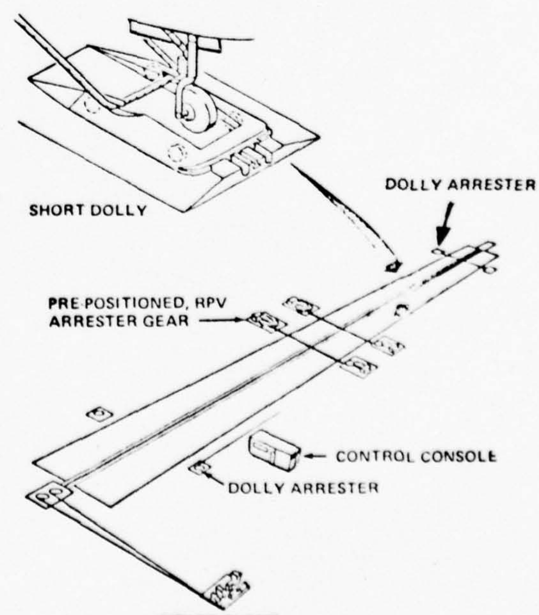
Remotely Controlled sleds with RPV in retainer frame. Launched when sled attains RPV launch speed. Sled is arrested by arrester gear after launch and returned automatically for next launch.



MARS Mid Air Retrieval System

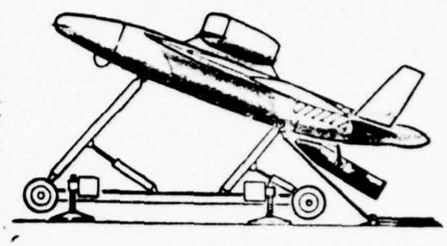
Existing air-to-air recovery system using either CH-3 or HH-53 helicopters. This system in case of failure of engagement requires an impact attenuation system for successful recovery.



Rubber Mat and Arrester Gear	Two vehicles equipped with foldable rubber decking provide an impact mat for a laser guided RPV after its arrestment by arrester gear cable.	
Mobile Catapult System (Runway Catapult)	A fully mobile catapult system utilizing a jet engine driving a power turbine. A continuous cable is driven by a capstan assembly connected to a combining gear box driven by the turbine. A rapid launch capability exists using nylon ropes dolly arrestment system for rapid return of the dolly to launch point. The system is fully air transportable.	

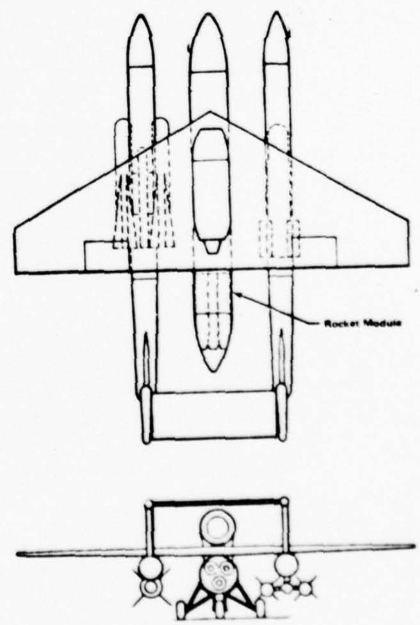
Zero Length Launcher with Thrust Vector Control (TVC)

Vehicle is supported on a launcher/transporter from which it is launched. The R.A.T.O. unit sustains the acceleration of the vehicle until flying speed is reached. Until that time the (TVC) unit maintains the control of vehicle attitude by control of thrust vector angle to move in the direction reducing RPV attitude errors during launch. RATO is jettisoned (falls off) on burn-out.

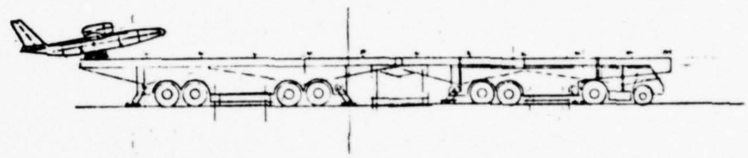


Internal RATO

Total thrust of the RPV is augmented by the addition of a rocket motor module. A single motor or a cluster of existing tactical missile motors can be employed. The module is carried onboard during the mission and is replaced after recovery.

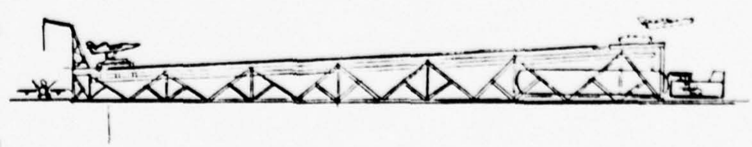


Hybrid Truck Launcher	RPV is launched from an RPV dedicated system of two vehicles employing interconnecting catapult rail with a rocket propelled shuttle. It is capable of launching RPV from any location and in any direction - once the alignment of the vehicles and their ground stability is obtained.



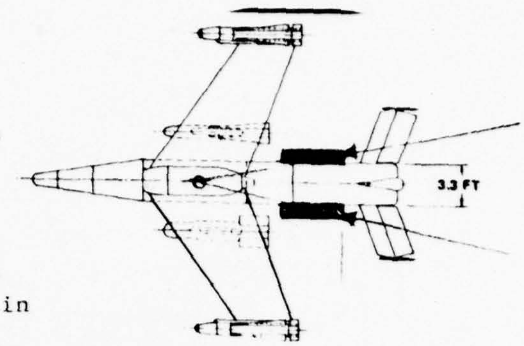
A shuttle is arrested at the end of stroke by a snubbing device at high deceleration levels (100 gs) in a very short distance. After completion of load cycle, shuttle is returned and loaded with a new insert for the RATO. The system is air transportable.

Rail Catapult	A ground installed steam or air pressure catapult. It is a static installation with a power plant and pressure tank. The system is air transportable and rapidly erectable. RPV support shuttle after working stroke is decelerated by a high g snubbing device.



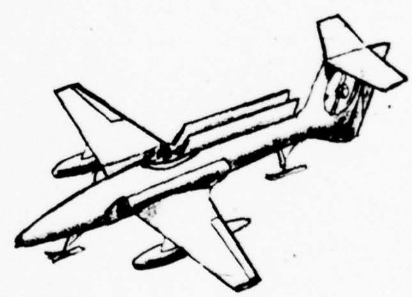
External JATO

Two (or one centrally located) JATO bottles are attached to the vehicle for propulsion assist during take-off. They separate after burn-out and are not recoverable for use. Their light-up timing is critical in order to obtain best performance.



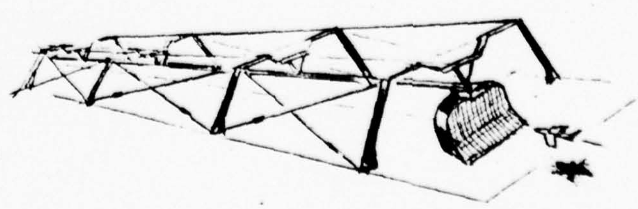
Foldable Rotor System

RPV takes off conventionally or is catapulted with its rotor stowed. On recovery rotor lock is released and activated to act as a lift device for a recovery as an autogyro. The rotor in the fin is spun by a main engine airbleed acting on an air motor driving the rotor. The cyclic pitch of the rotor and the pitch of the tail rotor are controlled by the autopilot. Recovery is made on wheels or skids.



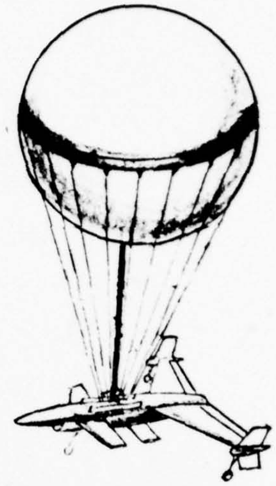
Hi-Line Arresting System

An overhead suspended arrest system with a capture mitt into which the vehicle flies at approach speed. The terminal guidance accuracy is essential, as once committed the vehicle cannot make an over-shoot. Deceleration is accomplished by restricting the slippage of the line carrying the suspension of the mitt.



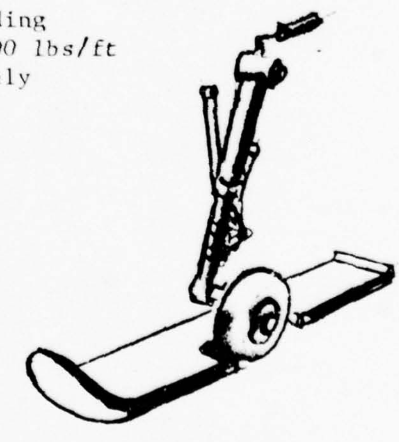
Integral
Balloon

This system was invalidated on account of incompatibility with remotely piloted vehicle's concepts. The system requires too much weight and volume of liquid gas and balloon material to satisfy ARPV vertical landing ground contact requirements.



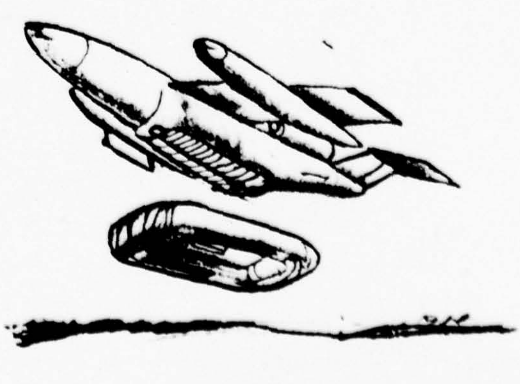
Wheels/Skis
(Snow Interface)

A typical wheels/skis combination. This interface is fully retractable. A unit loading normally used is between 200-400 lbs/ft The aspect ratio of approximately 6 and maximum front bow angle between 20^{o} and 25^{o} are common.



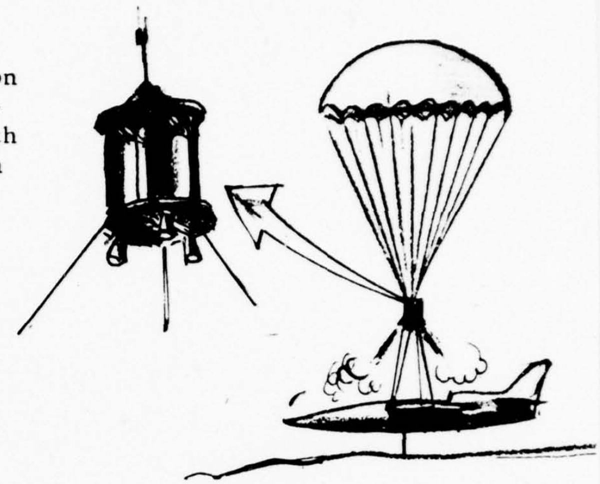
External
Air Cushion
Dolly (Droppable)

An air cushion system similar to the one presently undergoing development on Jindivik drone. The external cushion trunk assembly is droppable after the vehicle attains take-off speed.



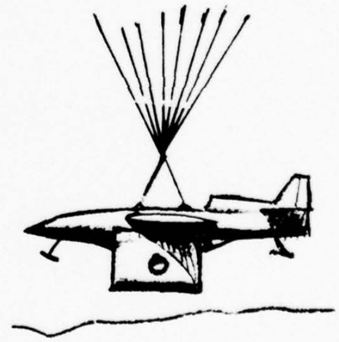
Retro-Rocket

The system for deccelerating vertically descending loads on the parachute. The main components are - rocket pack with parachute and load suspension bridles, the ground sensing probes with contacting lines and probe led-out mechanism and the pyrotechnics to trigger motor ignition.



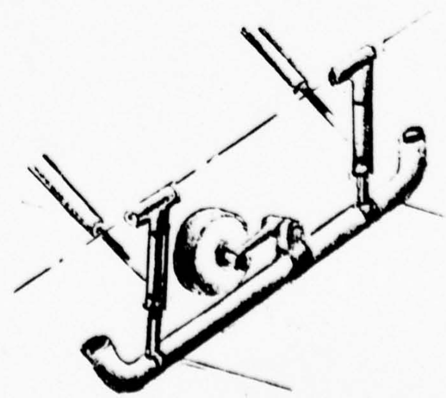
Air Bag Impact Attenuator

An internally or externally stored low pressure, flexible gas bag. It is located directly under the vehicle C of G and is either repackageable or replaceable after use. It is made of nylon cloth impregnated with NATSYN ELASTOMER. The bag contains blow-off orifice assembles to relieve pressure during impact. The system can be inflated by a gas bottle activated by pyrotechnic means via barometer sensor. An aspirator in the bag system maintains the bag relative pressure at a desired level during descent. The system normally should incorporate parachute jettison mechanism on impact.



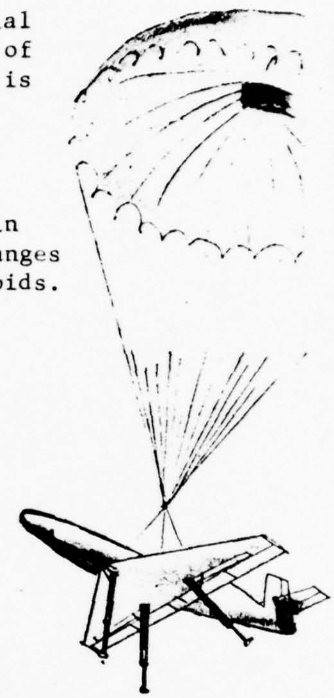
Skids/Wheels

A retractable skid with a wheel added for ease of ground handling. After landing a lever is inserted into the wheel bushing and the wheel rotated to a new fixed position rising the vehicle off the skids for towing.



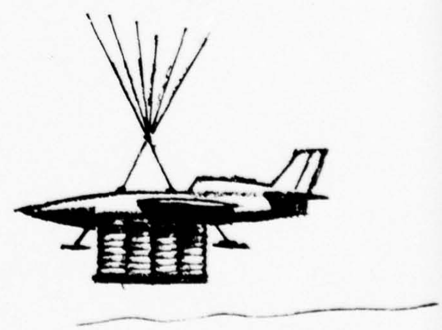
Impact Attenuators

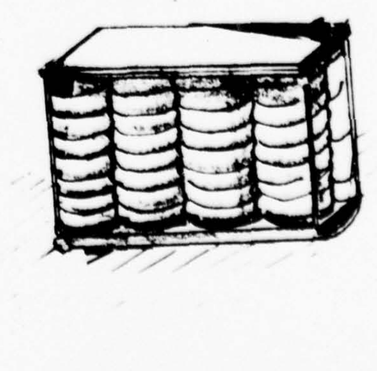
The concept is based on the commercial impact absorbing device by the name of TOR-SHOCK . The principle employed is conversion of kinetic energy into a non destructive deformation of material (wire) pressed between the two displacing metal tubes. The movement between the two cylinders in compression on impact constantly changes the eliptical axes of the wire torroids. The system can be reset for reuse.



Pallet and Air Bags

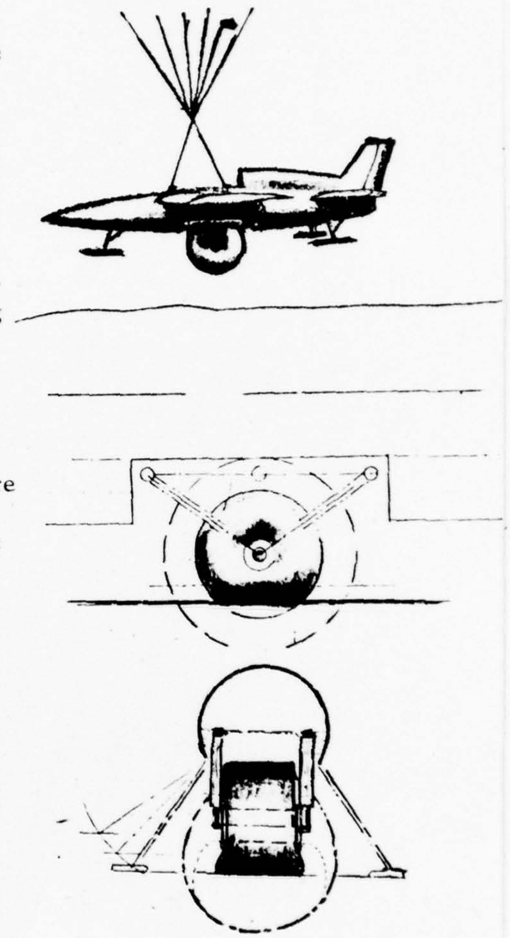
Basically a system of separately inflatable bladders attached at one end to the vehicle insert and at the other to the pallet which in flight forms an integral closure at the bottom of the vehicle. The system consisting of high pressure storage bottles, initiation valves, regulators/ aspirators and 6-8 attenuator bags are all contained in a replaceable module. The actuation of the system is by barometer. After system blow-off on impact the vehicle comes to rest on the shock pads extendable at the time of pallet initiation.





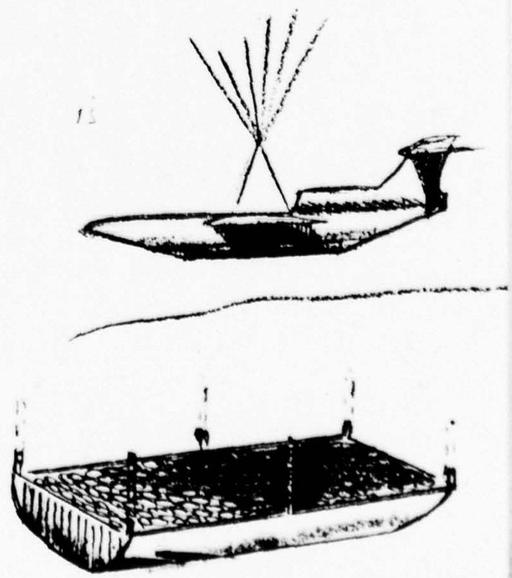
Low Pressure Tire

This system utilizes an expandable low pressure tire for impact attenuation and vehicle mobility after impact. It works in conjunction with a large canopy diameter parachute to reduce the velocity of impact to less than 20 ft/sec. When retracted the tire is deflated in order to minimize the volume requirements. Long stroke impact shock absorbers support the tire in the extended position and absorbs the impact logistics with the deflection of the tire. A blow-off valve is incorporated to reduce the pressure during impact. This action also reduces tire size to allow vehicle tow after recovery. Three retractable skids stabilize the vehicle after recovery.



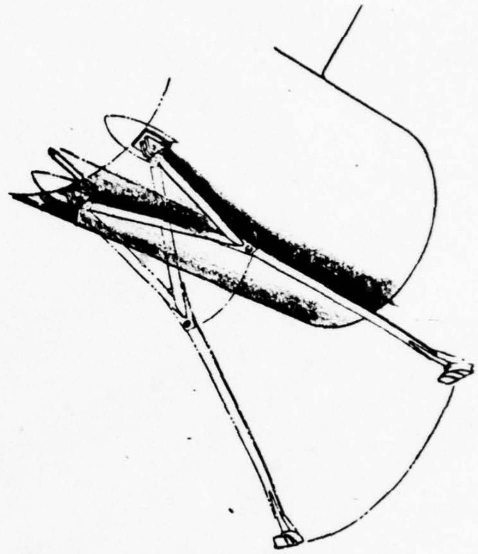
Body Impact Reinforcers

The parachute descent kinetic energy is absorbed by the deformation and deflection of the honeycomb core material built into exchangeable attenuator pallet which is discarded after landing. A moderate g level can be attained - (7.0g) provided the impact force can be evenly distributed.



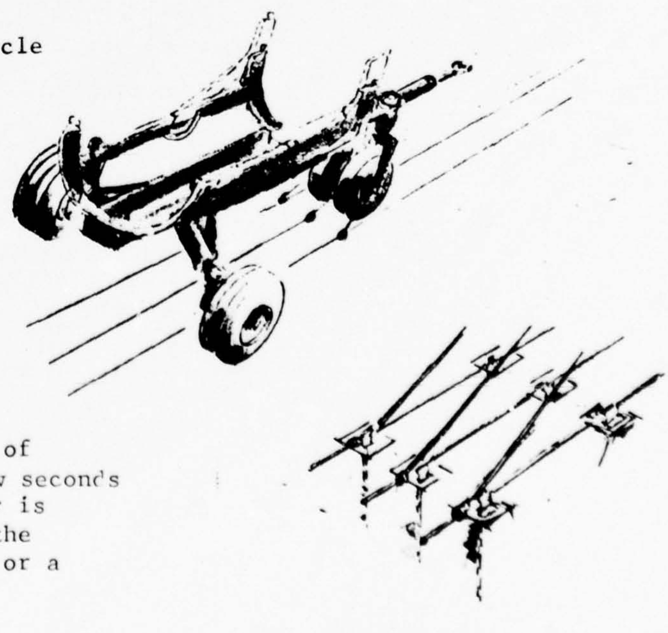
Spring Lead Arresting Hook (A.A.E. Sheaffer Hook)

The hook assembly comprises a shank made out of a flat steel spring attached at one (or two pronged ends as shown) to the fuselage and at another to a hook point or shoe. In its stowed position the hook is held against the spring force by a latch device. When latch is released the hook snaps into position with the spring force holding the hook against the runway.



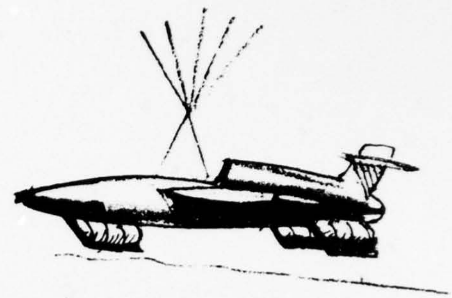
Wire Guided Dolly

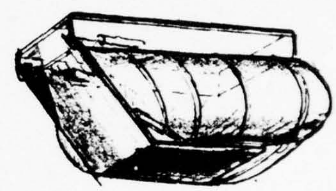
The nose wheel of the tricycle dolly is held on a given heading by a set of ground wires embedded in flat top stakes driven to the ground. The connecting arms are attached at one end to the wires, over which they slide, and at the other to the power steering mounted above the front axle. Vehicle leaves the dolly after attaining takeoff speed. Dolly is slowed down by application of close circuits brakes a few seconds after the load on the dolly is released. It is towed to the point of launch by a truck or a jeep.



Skids/
Airbags

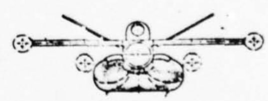
This concept uses a three point configuration of airbags combined with hinged skids for recovery. After impact the vehicle can be towed away on the skids with partially inflated airbags. The system is retractable for next sortie using vacuum pump and pneumatic jacks. Airbag attenuation principles (blow-off valves, low pressure with aspirators) are used. Delta configurations appear most suitable for this concept.

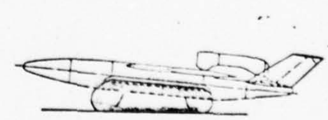




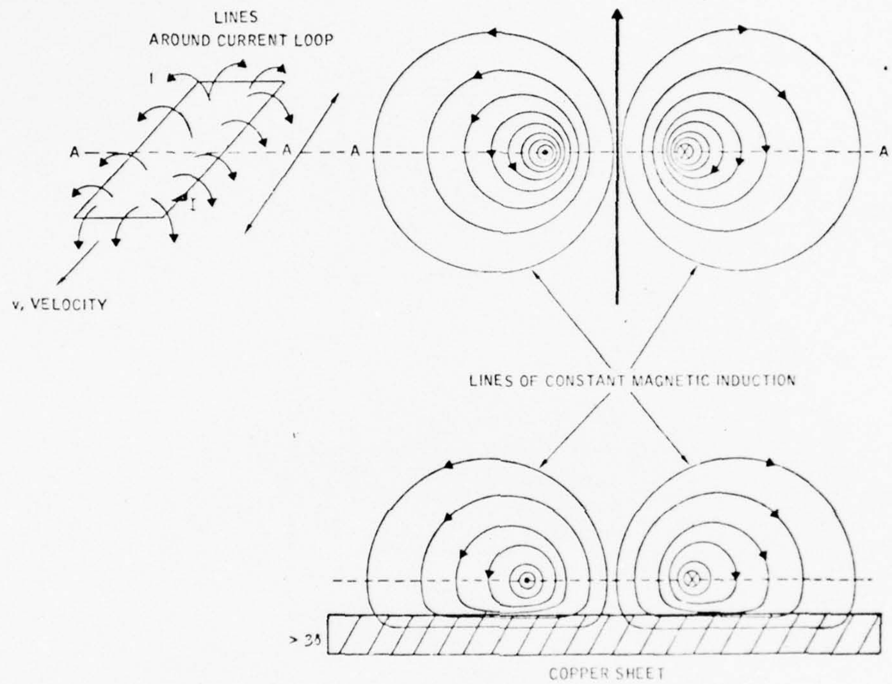
Integral
Air Cushion
Landing System
(ACLS)

The elastic trunk of this system is self retracting to the contour of the vehicle body. A bi-directional stretch material is used to avoid wrinkles, gathers or bulges when retracted. The packing system for the ACLS consists of separate bladders which are inflated in the normal trunk and remain inflated as required. The system connects to air pressure supply which can be either a compressor bleed air or a separate turbine. Steering of the ACLS is done by differential braking of the brake pillows which are separate bladders with abrasive resistant material.





PRINCIPLE OF MAGNETIC LANDER



A. WIRE LOOP MOVING OVER A CONDUCTIVE SHEET

The loop carries current I and moves with velocity v parallel to the conductive sheet.

B. CROSS SECTION OF LOOP FAR FROM THE CONDUCTING SHEET

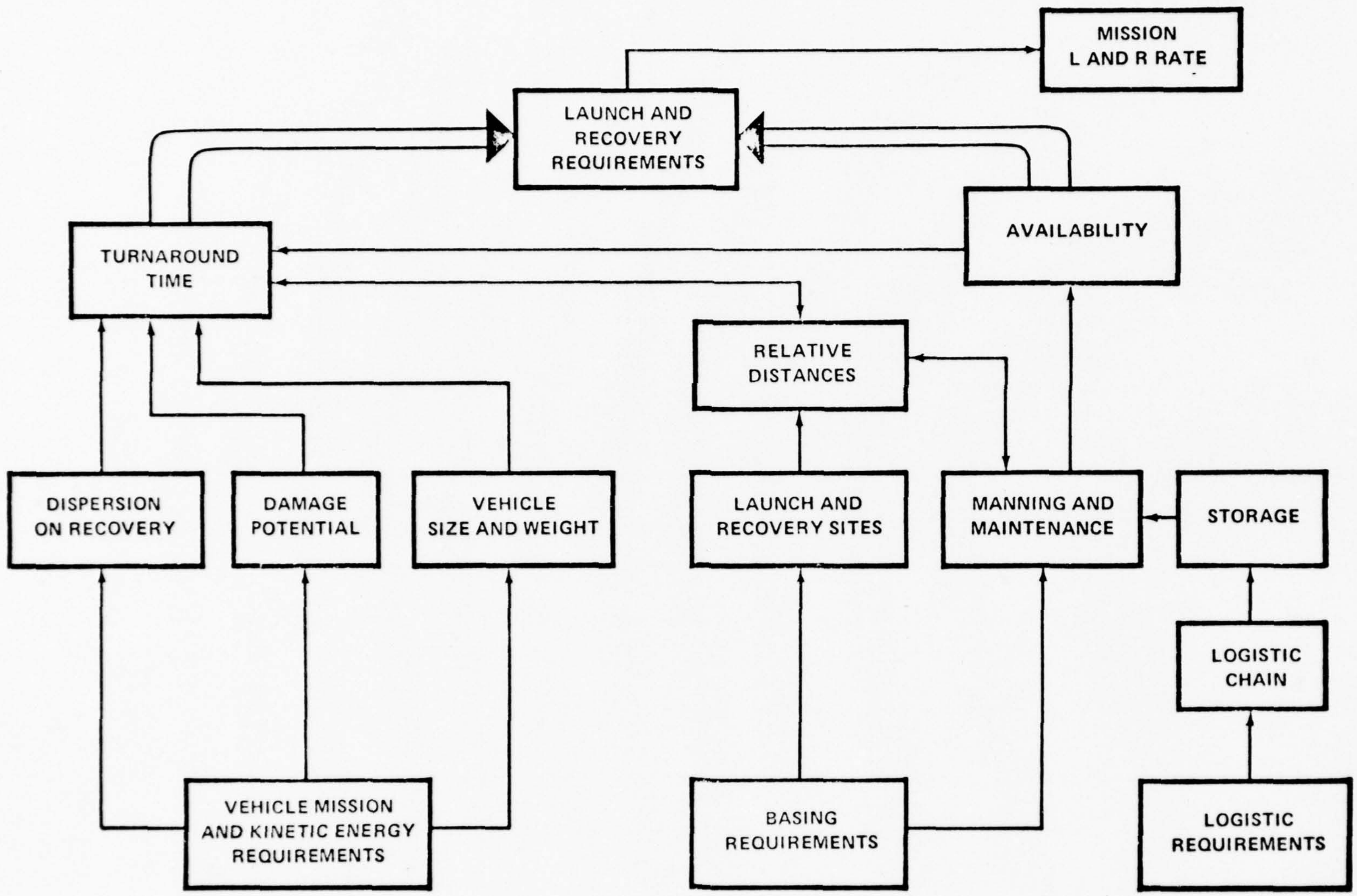
While far from the conductive sheet, the magnetic flux lines around opposite pairs of wires are circular.

C. CROSS SECTION OF LOOP NEAR CONDUCTIVE SHEET

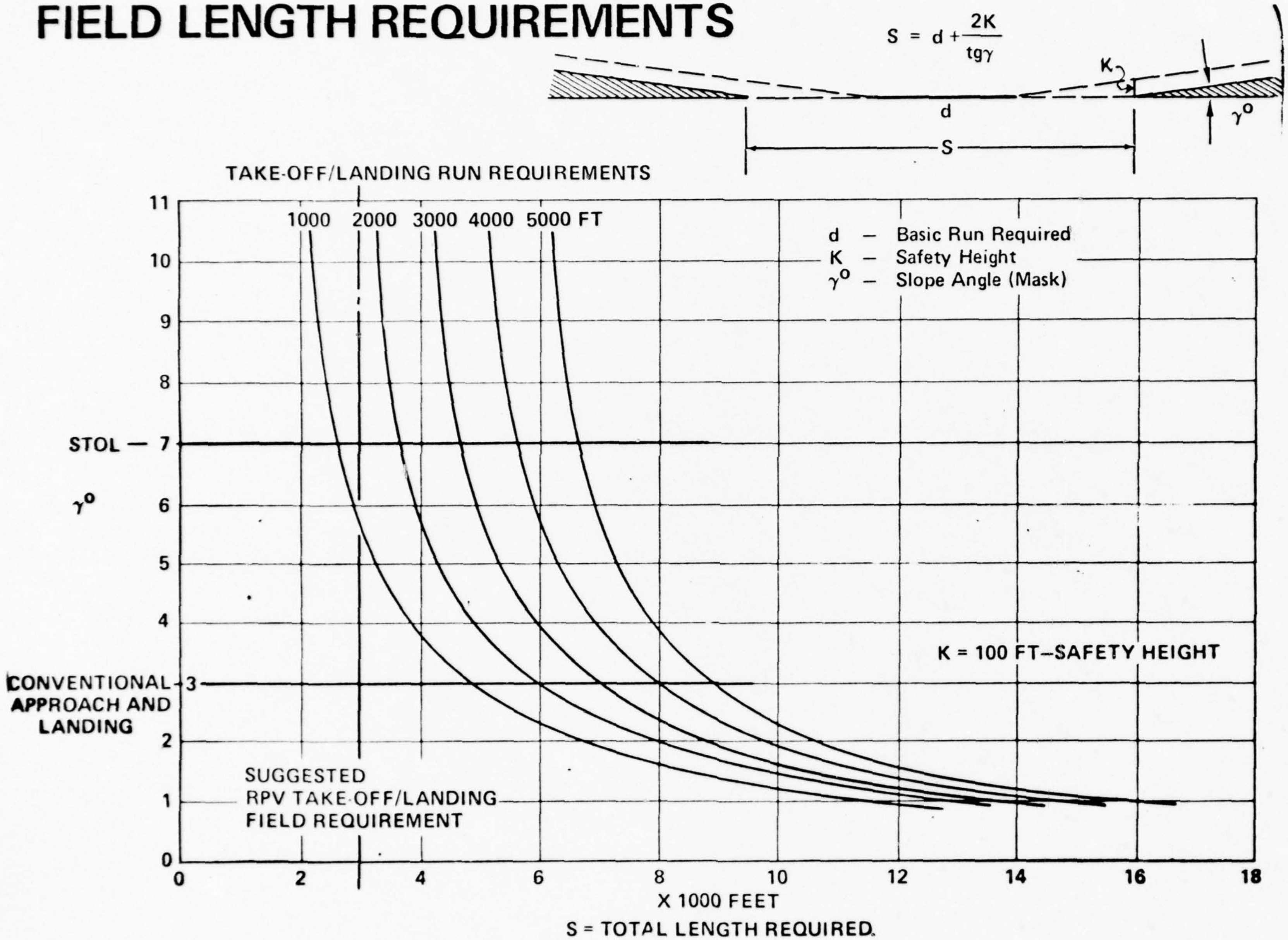
The circular flux lines are compressed and forced out of the conductive sheet by eddy current flowing in the sheet. As a result, the loop is repelled from the sheet and experiences a drag force opposite in direction to the velocity.

DEVELOPMENT OF LAUNCH & RECOVERY REQUIREMENTS

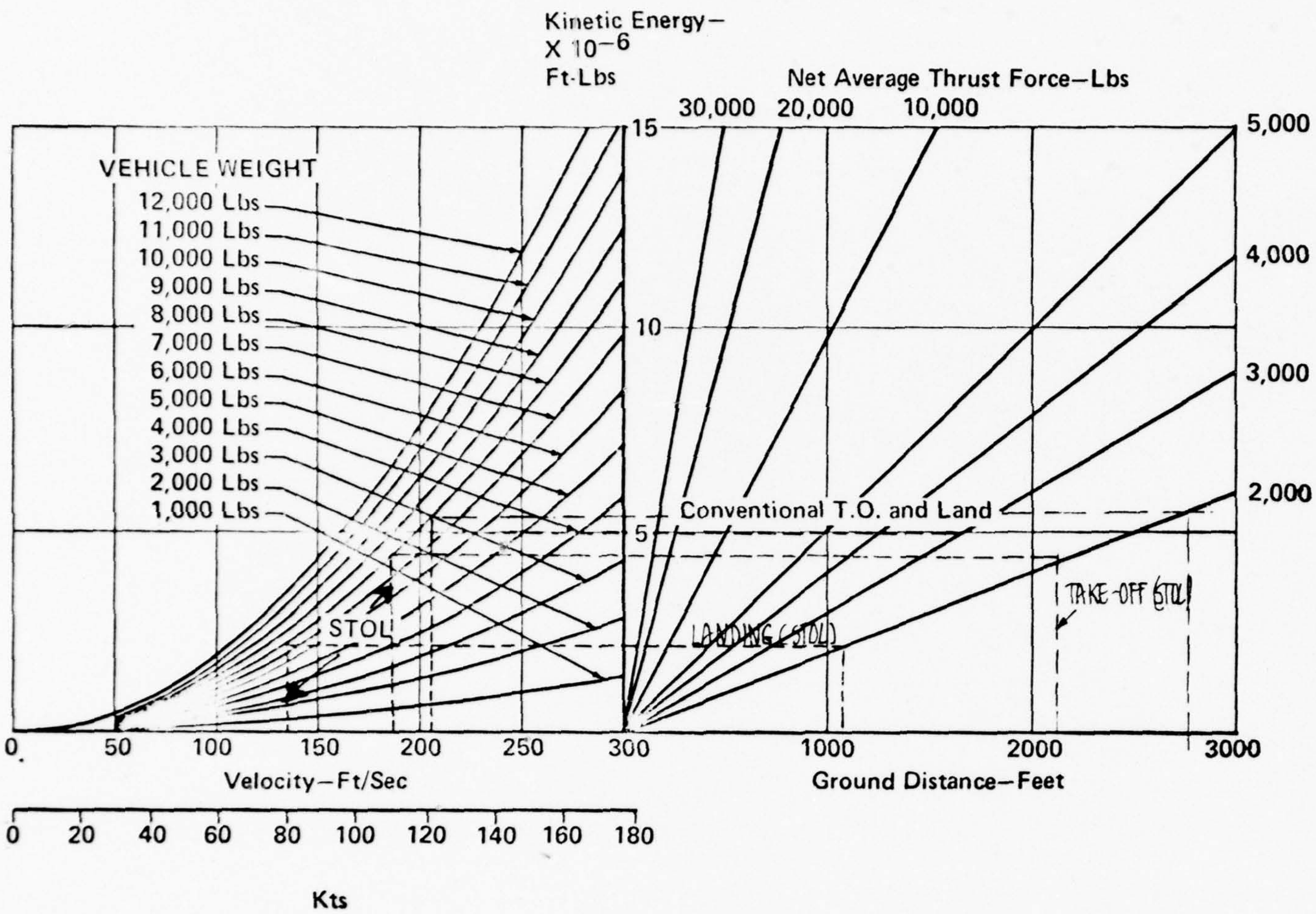
LAUNCH AND RECOVERY REQUIREMENTS TREE



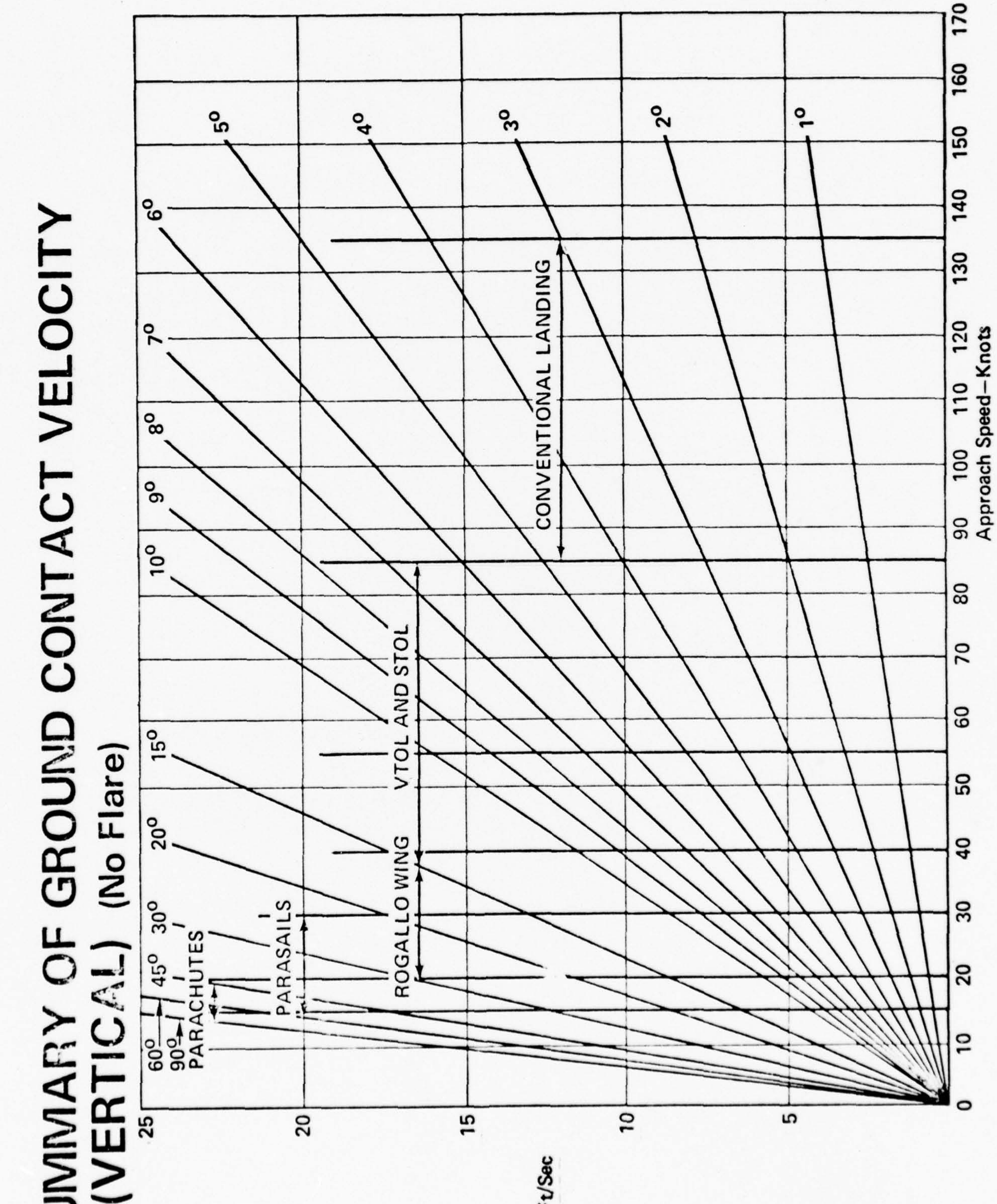
FIELD LENGTH REQUIREMENTS



KINETIC ENERGY LEVELS



SUMMARY OF GROUND CONTACT VELOCITY (VERTICAL) (No Flare)



SUMMARY OF LAUNCH & RECOVERY REQUIREMENTS
(Provisional)

SITE REQUIREMENTS

- DIMENSIONS - 3000 x 3000 Ft TYPICAL DIMENSIONS
- ACCESSIBILITY - ROAD TRANSPORT - MOBILITY III (Overland)
- GROUND SLOPE - 2 PERCENT - MAXIMUM CHANGES FOUR
- MASK ANGLE (FIELD BOUNDARY) - 10^{0} LAUNCH - 3^{0} RECOVERY
- GROUND HARDNESS - CBR 4
- SURFACE - GRASS, MACADAM, STEEL OR ALUMINUM MAT
- DISTANCE TO LOGISTIC BASE - 15 NM MAXIMUM
- SERVICES REQUIRED - WATER (Minimum)
- LOGISTICS SUPPLY (POL, ARM) - PREPLACED IN ADVANCE

EQUIPMENT

ALL AIR TRANSPORTABLE - C-130, C-141
MINIMUM OFF VEHICLE EQUIPMENT
ALL POWER TO BE SELF-GENERATED

SET-UP TIME - 36 HOURS FROM DELIVERY TO SITE

WIND-DOWN TIME - 6 HOURS (LAUNCH & RECOVERY COMBINED)

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SUMMARY OF LAUNCH & RECOVERY REQUIREMENTS (CONTINUED)
(Provisional)

LAUNCH OPERATIONS	
LAUNCH RATE PER SQUADRON	20 VEHICLES PER HOUR
VEHICLE SURVIVAL IN LAUNCH PHASE	99 PERCENT
ABILITY TO ORIENT TO WIND	30 MINUTES
RECOVERY OPERATIONS	
NAV ACCURACY AT ACQUISITION POINT	CIRCLE 1/2 nm RADIUS
ACQUISITION POINT FROM APPROACH CONTROL	30 nm
ACQUISITION POINT FROM RECOVERY CONTROL	10 nm
AVERAGE GLIDE PATH ANGLES	Up to 7^{0} - STOL Up to 45^{0} - Med. Slope 60 to 90^{0} - Vertical Slope
APPROACH GLIDE PATH ACCURACY	Track Hold ± 50 ft Glide Path ± 10 ft
ACCURACY OF TOUCHDOWN ALONG TRACK	± 150 ft

SUMMARY OF LAUNCH & RECOVERY REQUIREMENTS (CONTINUED)
(Provisional)

LATERAL ACCURACY AT TOUCHDOWN	±25 ft (STOL)
ACCURACY OF CONTACT	±3 ft (Airborne AIM for Air Recovery Systems)
TOWING DISTANCE FROM RECOVERY TO TURN-AROUND AREA	2 nm (Typical)
DAMAGE REPAIR AT TURN-AROUND	4 Hours Max
ACTUAL TURN-AROUND TIME	Less than 30 Minutes
ABILITY TO ORIENT TO WIND	30 Minutes
SURVIVABILITY IN RECOVERY PHASE	Ground 0.994 (95% Confidence) Air 0.95 (95% Confidence)

SUMMARY OF LAUNCH & RECOVERY REQUIREMENTS (CONTINUED)
(Provisional)

VEHICLE REQUIREMENTS

● INSERTION INTO GROUND LAUNCH SYSTEM	1 Minute (Max)
● INSERTION INTO AIR LAUNCH SYSTEM	10 Minutes (Max)
● PRELAUNCH CHECKOUT COMPLETE	In 2 Minutes (Max)
● LONG ACCELERATION (Max)	15 G (Catapult Rail)
● LAT ACCELERATION DURING LAUNCH	3 G (Max)
● LAUNCH HEADING HOLD	± 1 Degree
● LAUNCH ATTITUDE HOLD	±2 Degrees
● RECOVERY DECELERATION (Long)	6 G (Max)
(Lateral)	3 G
● VERTICAL SINK RATE (STOL) (No Flare)	Up to 20 Ft/Sec
● CONFIGURATION CHANGE (STRIKE, EW, RECCE)	2 Hours (Max)

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SUMMARY OF LAUNCH & RECOVERY REQUIREMENTS (CONTINUED)
(Provisional)

- DESIGN TO MINIMUM MAINTENANCE REQUIRED
- DESIGN TO MINIMUM VEHICLE/LAUNCH SYSTEM INTERFACE
- LAUNCH & RECOVERY SYSTEM TO RESULT IN MINIMUM DRAG/WEIGHT PENALTY CONSISTENT WITH MISSION
- BACK-UP EMERGENCY RECOVERY SYSTEM — STRIKE - None; EW - None; RECCE - Parachute
- RPVs POINT OF PLACEMENT FROM DESIGNATED RECOVERY AIM POINT — 150 Ft Radius Circle (Max)

SUMMARY OF LAUNCH & RECOVERY REQUIREMENTS (CONTINUED)
(Provisional)

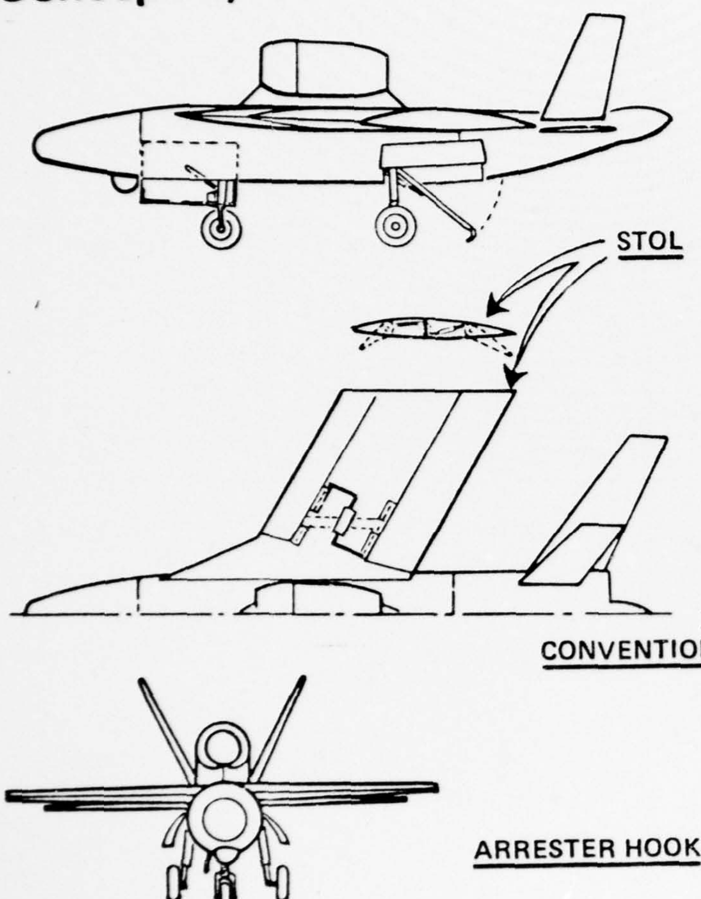
<u>GENERAL REQUIREMENTS</u> (LAUNCH & RECOVERY)

- LAUNCH & RECOVER INTO WIND (preferably)
- CARRY INTEGRAL MOORING ATTACH POINT
- PROVIDE INTERNAL GO/NO-GO INDICATOR AND FUEL AND GEAR LOCK INDICATOR IN THE SAME LOCATION
- PROVIDE EASE OF ACCESS BY GROUND CREW
- VEHICLE MUST REMAIN STABLE AND STATIONARY WHEN PARKED ON 10 DEGREE SLOPE
- REFUELING POINTS TO BE <u>EASILY</u> ACCESSIBLE
- MODULAR SECTIONS TO HAVE QUICK DISCONNECTS - 1 Man - No Tools)
- PROVIDE COMPATIBILITY WITH TAC OPERATIONS
- PROVIDE COMPATIBILITY WITH RPV CONTROL SYSTEM
- PROVIDE FOR MINIMUM GROUND SUPPORT EQUIPMENT
- SYSTEM TO BE USABLE BY ALL COMMANDS

CONCEPT DEVELOPMENT

(ASSOCIATED L&R ELEMENTS)

STOL–CONVENTIONAL GEAR–ARREST HOOK
(Concept 1)



INTERNAL WING ACTUATION OF STOL CONFIGURATION
- LEADING EDGE DROOP FLAP AND TRAILING FLAP CONTROLS
- ACTUATORS (1 PER WING)
- BELLCRANKS
- PUSH-PULL RODS
- CO-ROTATING TORQUE TUBES AND ATTACHMENTS
- WIRING AND CONNECTORS
- COMMAND SENSORS (IN VEHICLE)

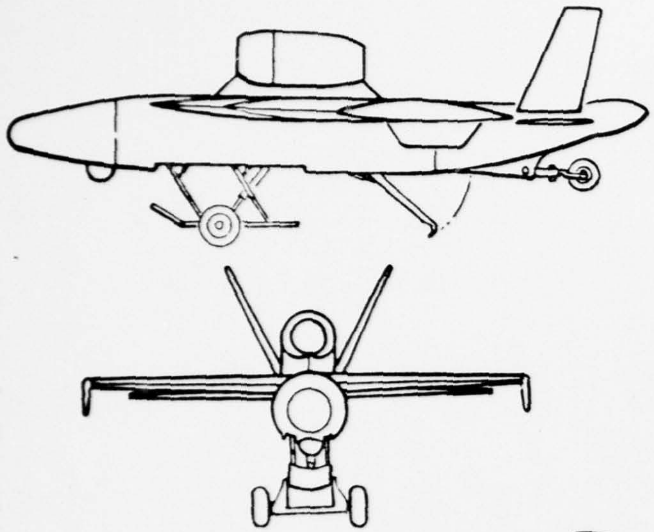
TOTAL WEIGHT PER VEHICLE 100 POUNDS (ESTIMATED)

NOSE GEAR HOUSING–2 CUBIC FEET
MAIN GEAR HOUSING–10 CUBIC FEET
- SHOCK ABSORBERS/STRUTS (3)
- DRAG LINKS AND LOCKS (3)
- ACTUATORS (3)
- WHEELS (3)
- DOOR OPENING AND CLOSING MECHANISM (2)
- UP-DOWN LOCK MECHANISMS, SWITCHES, AND WIRING
- INTERNAL STRUCTURAL GEAR PIVOTS AND SUPPORTS

- LATCH MECHANISM
- SHOCK ABSORBER AND HOLD DOWN CYLINDER
- HOOK
- INTERNAL STRUCTURAL HOOK PIVOT AND SUPPORT

TOTAL WEIGHT GEAR 351 POUNDS HOOK 51 POUNDS

STOL + WHEEL DOLLY + SKID(S) + ARRESTER HOOK SYSTEM (Concept 2)



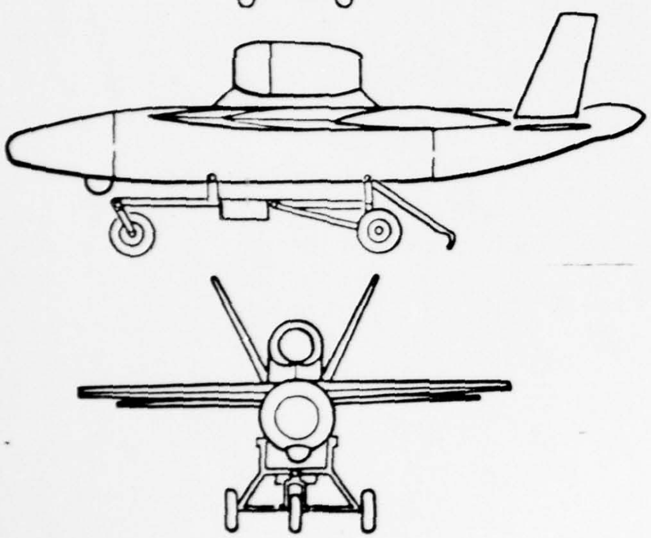
STOL — AS PER CONCEPT 1

2-WHEEL DOLLY SUSPENDED FROM CENTER SKID (DROPPABLE AFTER LAUNCH)

- WHEELS (2) WITH CONNECTING STRUCTURE
- SKID ENGAGEMENT INTERFACE
- LATCH AND LOCK RELEASE MECHANISM WITH WIRING
- VEHICLE INTEGRAL TAIL WHEEL

3-WHEEL DOLLY–(FLY-OFF)

- HARD POINTS (DOLLY/VEHICLE/ INTERFACE)
- STRUCTURAL COMPATIBILITY FOR HARD POINT SUSPENSION
- CONTROL INPUT FOR FLY-OFF THE DOLLY (WIRE GUIDANCE OR MICRO ELECTRONICS).



CENTER LANDING SKID (INTEGRAL)

- SKID STRUCTURE (FLUSH WITH BODY)
- SUSPENSION–PARALLEL DRAG LINKS AND LOCKS (SWEPT VOLUME 6 CUBIC FEET)
- SHOCK STRUT(S)
- ACTUATOR AND ACTUATING SYSTEM
- LATCH AND LOCK RELEASE MECHANISM WITH WIRING

ARRESTER HOOK– AS PER CONCEPT 1

- PIVOT STRUCTURAL HOUSING
- WING TIP BUILT-IN CONTACT SKIDS

TOTAL WEIGHT INTEGRAL CENTER SKID 280 POUNDS (ESTIMATED)
HOOK 51 POUNDS

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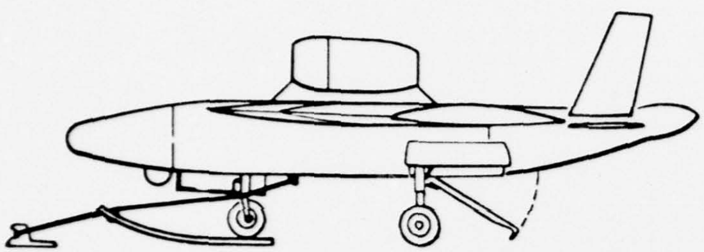
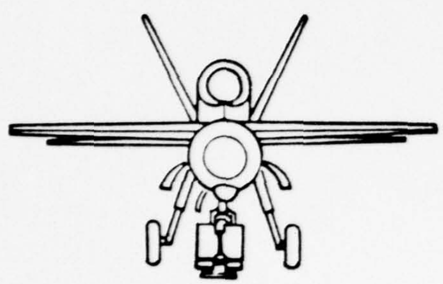
BASIC WING + LAUNCH CATAPULT + CONVENTIONAL GEAR + ARRESTER HOOK (Concept 3)





BASIC WING	• FIXED PROFILE WING
LAUNCH CATAPULT RPV EQUIPMENT	• BRIDLE HOOKS ATTACHED TO STRUCTURAL MEMBERS • CATAPULT HOLDBACK ATTACHED TO HOOK HOUSING
CONVENTIONAL GEAR	• BEEFED-UP NOSE GEAR UNIT AND PIVOT ATTACHMENTS • BEEFED-UP MAIN GEAR UNIT FOR LONG CATAPULT STROKE AND HIGHER TOUCHDOWN SPEED
ARRESTER HOOK	• AS PER CONCEPT 1

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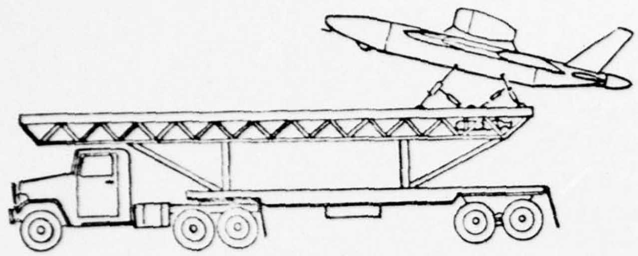
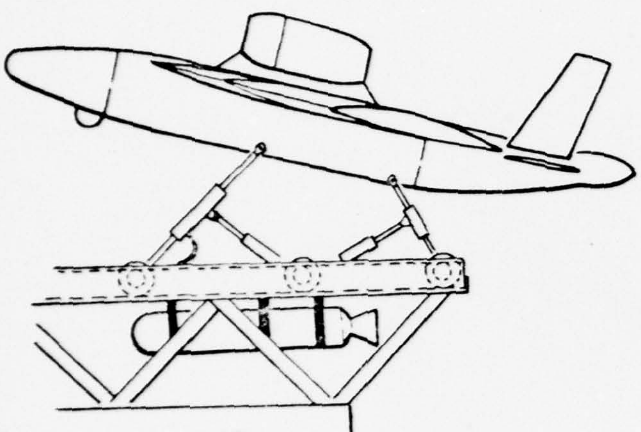
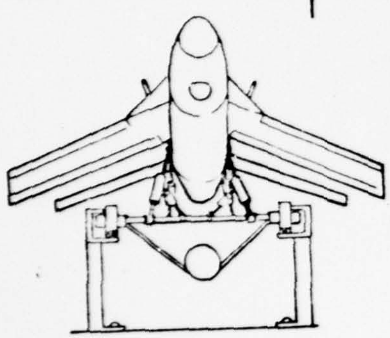
STOL + HYBRID TRUCK LAUNCHER + CONVENTIONAL GEAR + ARRESTER HOOK (Concept 4)







STOL — AS PER CONCEPT 1

HYBRID TRUCK RAIL CATAPULT RPV EQUIPMENT

- BODY-HARD POINT INTERFACE RECEPTACLES FOR RAIL CATAPULT SHUTTLE
- RPV/SHUTTLE HOLDBACK ATTACHED TO HOOK HOUSING (SHUTTLE HOLDBACK ATTACHED TO LAUNCHER STRUCTURE)

CONVENTIONAL GEAR

- GRAVITY DROP LANDING GEAR—OTHERWISE AS PER CONCEPT 1

ARRESTER HOOK

- AS PER CONCEPT 1

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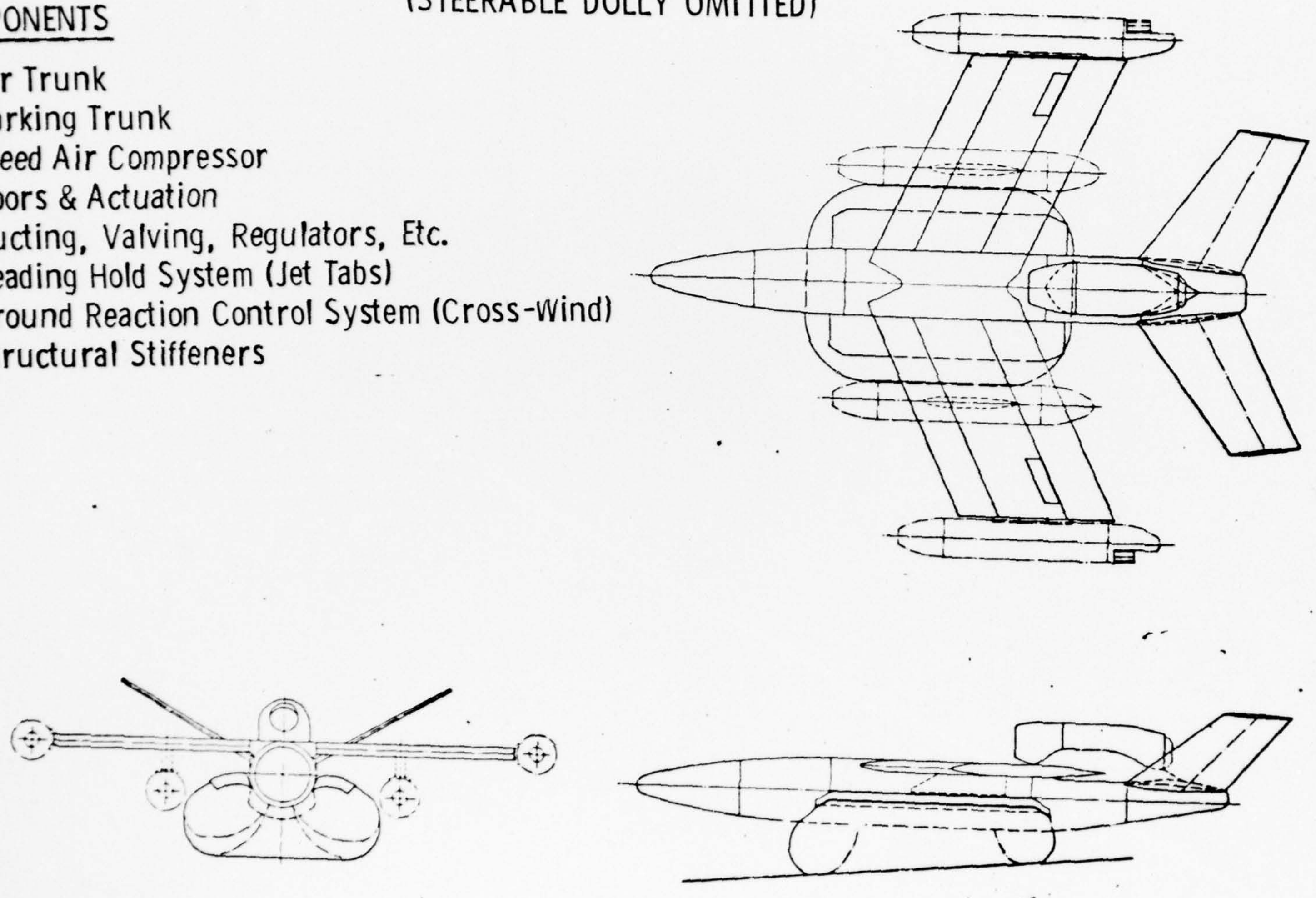
-INTEGRAL AIR CUSHION- (Concept 5)

(STEERABLE DOLLY OMITTED)

COMPONENTS

1. Air Trunk
2. Parking Trunk
3. Bleed Air Compressor
4. Doors & Actuation
5. Ducting, Valving, Regulators, Etc.
6. Heading Hold System (Jet Tabs)
7. Ground Reaction Control System (Cross-Wind)
8. Structural Stiffeners



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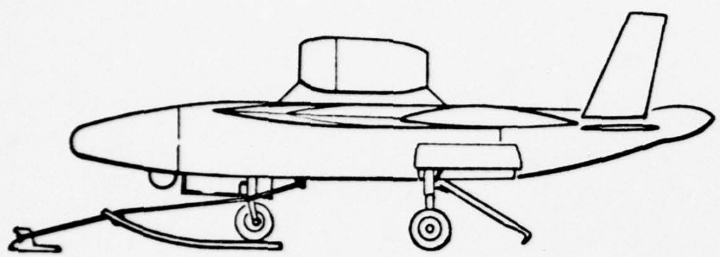
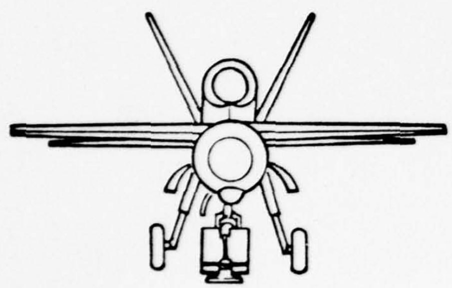
STOL + LAUNCH CATAPULT + CONVENTIONAL GEAR + ARREST HOOK (Concept 6)





STOL	AS PER CONCEPT 1
LAUNCH CATAPULT VEHICLE EQUIPMENT	• BRIDLE HOOKS ATTACHED TO STRUCTURAL MEMBERS • CATAPULT HOLDBACK ATTACHED TO HOOK HOUSING
CONVENTIONAL GEAR	• BEEFED-UP NOSE GEAR STRUT AND HOUSING
ARRESTER HOOK	• AS PER CONCEPT 1

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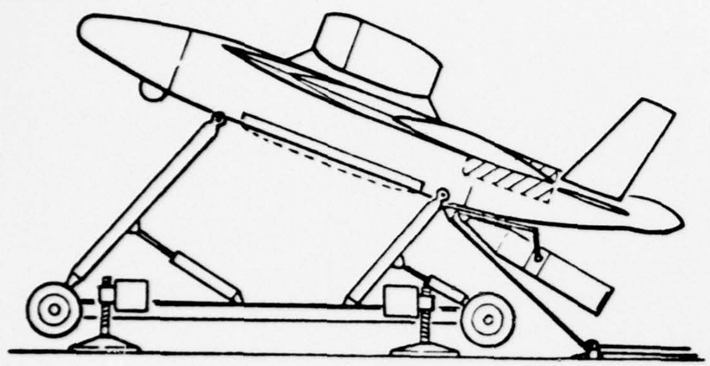
BASIC WING + ZERO LENGTH LAUNCHER (TVC) + PARACHUTE + AIRBAG ATTENUATOR (Concept 7)

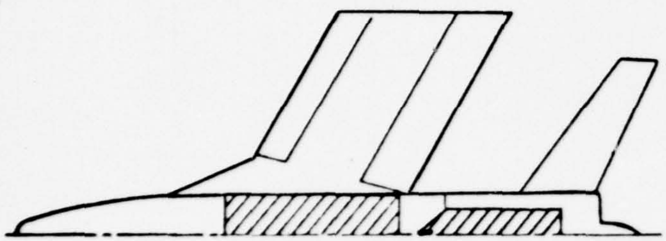


BASIC WING

- FIXED PROFILE WING
- HARD POINTS FOR ZEL (TVC)/ LAUNCHER INTERFACE

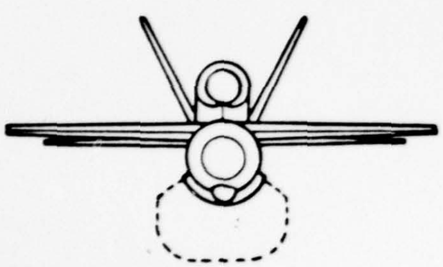
ZERO LENGTH LAUNCHER (RATO) WITH THRUST VECTOR CONTROL–VEHICLE RELATED EQUIPMENT

- FUSELAGE STRUCTURE BEEF-UP FOR 5–6 G LONGITUDINAL ACCELERATION
- FUSELAGE HARDPOINTS FOR ZEL (TVC) LAUNCHER INTERFACE
- VEHICLE HOLDBACK DEVICE
- INTERFACE CONTROL UNIT FOR TVC TABS (IN THE VEHICLE)
- ROCKET MOTOR BLAST AND CONTACT DEFLECTION PLATE AT BOTTOM OF FUSELAGE
- FUSELAGE STRUCTURE BEEF-UP FOR PARACHUTE DEPLOYMENT LOADS



PARACHUTE RECOVERY SYSTEM

- VOLUME FOR PARACHUTE AND DROGUE PACKS 6 CUBIC FEET MINIMUM
- PARACHUTE SYSTEM WITH STRIP-OFF BRIDLE LEGS ATTACHED TO PARACHUTE SUSPENSION POINT(S)
- PARACHUTE RELEASE SYSTEM AND PROTECHNICS
- TOTAL WEIGHT OF THE SYSTEM– UP TO 200 POUNDS



AIRBAG ATTENUATOR

- PACKAGE CONFIGURATION–INTERNAL OR EXTERNAL– STOWED PACKAGE VOLUME 3 CUBIC FEET FOR WRAP-AROUND BAG OF 150 CUBIC FEET INFLATED VOLUME. BAG WEIGHT 50 POUNDS BOTTLES AND INFLATION SYSTEM WEIGHT 60 POUNDS

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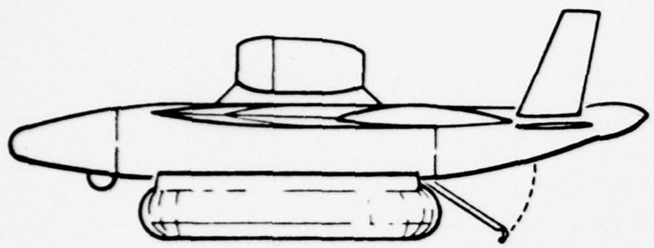
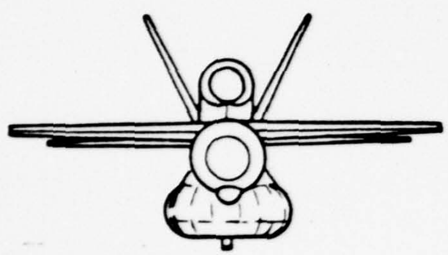
STOL–AIR CUSHION DOLLY–INTEGRAL AIR CUSHION–ARREST HOOK (Concept 8)





STOL	AS PER CONCEPT 1
AIR CUSHION DOLLY (DROPPABLE)	• TRUNK ATTACHMENT GIRT WITH VELCRO STRIPS • PLENUM AIR SUPPLY CHANNEL AND DIRECT BLEED HOLE WITH SEALS • AIR SUPPLY DUCTING AND VALVES FOR ACLS FAN • WIRING AND CONNECTORS • ACLS FAN AND HOUSING • NONEXPANDING AIR CUSHION TRUNK WITH PARKING TRUNK TOTAL VOLUME OF SYSTEMS IN VEHICLE–APPROXIMATELY 7 CUBIC FEET
INTEGRAL AIR CUSHION	• TRUNK ATTACHMENT GIRT AND BEAD • EXPANDABLE RECOVERY TRUNK WITH STOWAGE COVER AND RELEASE MECHANISM • NOZZLE ASSEMBLY FOR BLEED INLET • TRUNK PRESSURE RELIEF VALVES TOTAL WEIGHT OF INTEGRAL ACRS–APPROXIMATELY 125 POUNDS
ARRESTER HOOK	AS PER CONCEPT 1

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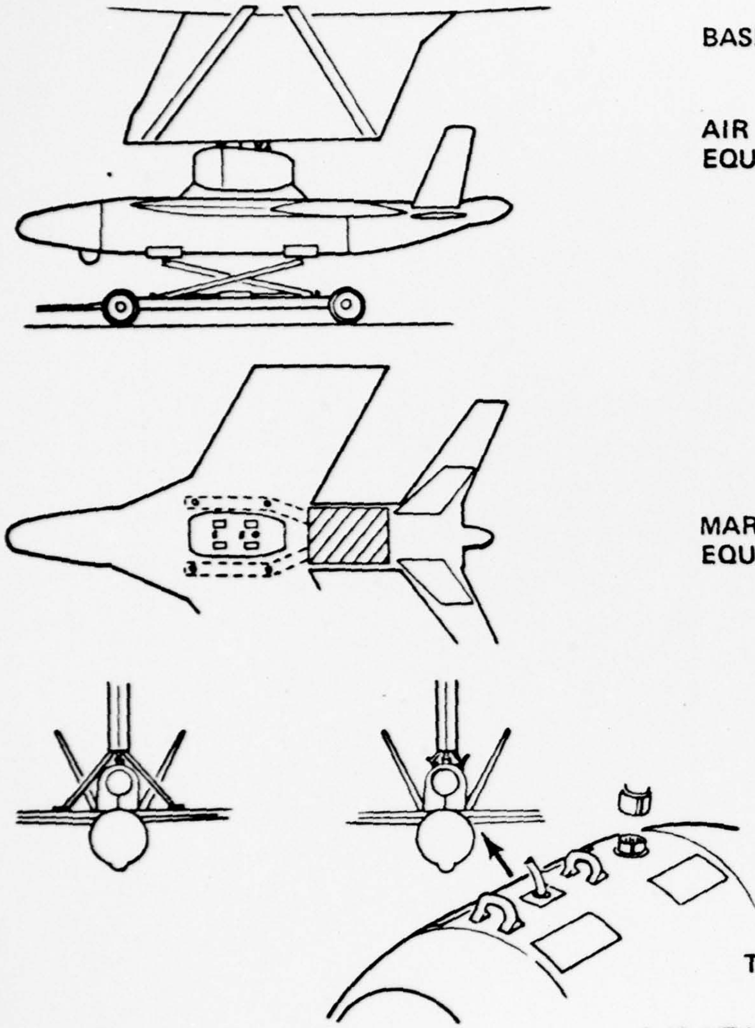
BASIC WING + DC-130 AIR LAUNCH + MARS RECOVERY (Concept 9)



BASIC WING

- FIXED PROFILE WING

AIR LAUNCH RELATED EQUIPMENT

- CARRY-THROUGH STRUCTURE FOR PYLON SUSPENSION
- VEHICLE/LAUNCH RACK INTERFACE– LUGS, SWAYBRACE PADS, FUEL LINE, UMBILICAL CONNECTOR–ALL ON TOP OF VEHICLE
- DIRECTIONAL FIN(S) LOCATION FOR PYLON CLEARANCE DURING CARRIAGE AND DROP
- HARDPOINTS FOR VEHICLE TO PYLON GROUND LOADER

MARS RELATED EQUIPMENT

- PACK FOR MAIN CHUTE, ENGAGEMENT CHUTE, LOADLINE
- RELEASE MECHANISM/BRIDLE STRIP-OFF CABLE AND LEGS
- FIRST STAGE PARACHUTE AND CONTAINER
- MAIN CONTAINER COVER DOORS (WITH RELEASE OR JETTISON MECHANISM)
- BRIDLE ATTACHMENTS TO CLEAR NACELLE ON CHUTE DEPLOYMENT
- BEEFED-UP STRUCTURE FOR PARACHUTE DEPLOYMENT LOADS

TOTAL SYSTEM VOLUME FOR AIR LAUNCH AND AIR RECOVERY– 8 CUBIC FEET WEIGHT 350 POUNDS

UNCLASSIFIED

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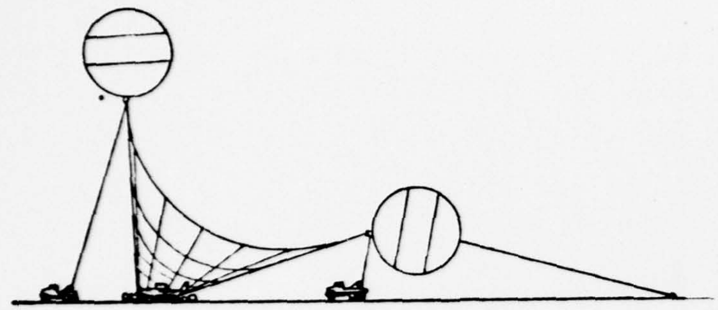
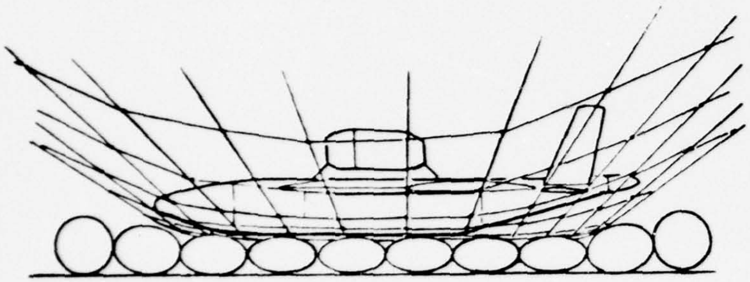
BASIC WING + RAIL CATAPULT + MITT + EXTERNAL AIR MAT (Concept 10)





BASIC WING

- FIXED PROFILE WING

RAIL CATAPULT VEHICLE RELATED EQUIPMENT

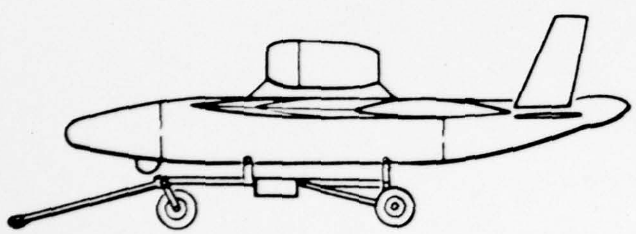
- TOTAL STRUCTURE BEEF-UP TO ACCEPT UP TO 15 G– LONGITUDINAL ACCELERATION
- BODY HARDPOINTS FOR RATO SHUTTLE INTERFACE
- VEHICLE HOLDBACK TO SHUTTLE (SHUTTLE HOLDBACK TO RAMP)

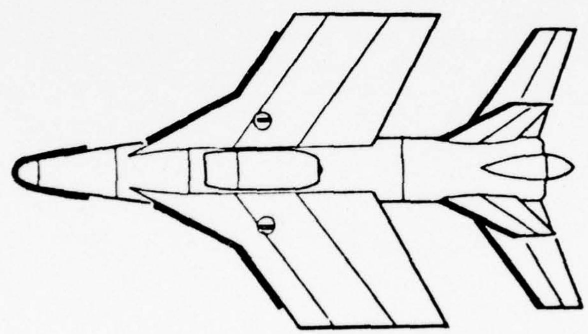
MITT RELATED EQUIPMENT

- WING, NACELLE, AND CONTROL SURFACES LEADING EDGE BEEF-UP FOR ENGAGEMENT IMPACT WITH MITT
- TOWING GEAR HARDPOINTS FOR DETACHABLE WHEEL DOLLY

AIR MAT RELATED EQUIPMENT

- ATTACHMENT POINTS FOR CRANE LIFT AT VEHICLE CENTER OF GRAVITY LINE





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ACLS - UTILITY ANALYSIS RESULTS

ADVANTAGES

- LOW CBR OPERATION (1.25 → UP)
- POSSIBLE EMPLOYMENT FROM WATER
- LOW PRESSURE SYSTEM
- GOOD DAMAGE TOLERANCE WHEN PRESSURE SYSTEM OPERATING
- PRESENTLY UNDER DEVELOPMENT
- MILD EFFECTS ON AIRCRAFT STRUCTURE

OTHER COMPARISON DATA

ALCS		CONV. HIGH FLOAT GEAR
SAME	COST PER SORTIE WEIGHT CONTRIBUTION LOGISTICS MAINTAINABILITY A/C STOWAGE VOLUME L. C. S. (10 year basis)	SAME

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ACLS - UTILITY ANALYSIS RESULTS (CONTINUED)

DISADVANTAGES

- FREEZING TO GROUND AFTER PARKING (Winter)
- GRADUAL COLLAPSE ON PUNCTURE OF PARKING BLADDER (When compressor not running)
- POOR LATERAL STIFFNESS (Asymmetric loading)
- CROSS WIND EFFECTS DIFFICULT TO CONTROL
- EASY ABRASION DAMAGE (Sharp ice, rugged edges)
- BAD BEHAVIOR ON SLOPES
- HEAVY DRAG IN MODERATE GRASS LENGTH
- LARGE AERO DRAG ON TAKE-OFF
- POOR ATTITUDE ROTATION CONTROL ON TAKE-OFF
- FREEZING AT HIGH ALTITUDE (Effects on material and joints)

ACLS - UTILITY ANALYSIS RESULTS (Continued)

DISADVANTAGES

- RECYCLE OF DEBRIS THROUGH ENGINE
- DOLLY MUST BE USED FOR DEAD ENGINE GROUND HANDLING
- HEADING HOLD PROBLEMS ON TAKE-OFF
- BLEEDS - ALREADY LOW ENGINE THRUST
- POOR ACCESS TO VEHICLE WHEN OPERATING (Volume & forced air effects)
- POOR STORES INSTALLATION (Lists)
- OXYDATION AND AGING (Fast)

C76-1324/034C